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THE BLAST FURNACE.

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The process of making cast iron in a blast furnace may be divided into three parts:

(1.) Deoxidizing the ore.

(2.) Carbonizing the deoxidized ore.

(3.) Liquefying the deoxidized ore.

All iron ores are essentially oxides, and may be divided into five species:

(1.) Protoxide of iron, in which the atomic ratio of oxygen to iron is one to one, as in fayalite.

(2.) Magnetic oxide of iron, in which the ratio of oxygen to iron is one and one-third to one, as in magnetite.

(3.) Sesquioxide of iron, in which the ratio of oxygen to iron is one and one-half to one, as in hematite.

(4.) Hydrated sesquioxide, in which the ratio of oxygen, iron, and water is one and one-half to one, to three-fourths, as in limonite.

(5.) Carbonate of protoxide of iron, in which the ratio of oxygen, iron and carbonic acid is one to one to one, as in siderite.

In addition to the above, there is the artificial ore or rolling-mill cinder, from which iron is extracted, and which corresponds in composition to fayalite.

Practically, in facility for reduction, these ores rank as follows:

(1.) Siderite or carbonate.

(2.) Limonite or hydrate.

(3.) Hematite or sesquioxide.

(4.) Magnetite or magnetic oxide.

(5.) Fayalite or silicate of protoxide of iron.

The magnetic oxide is a firm stable compound and retains its oxygen tenaciously. In some cases as with that from Pilot Knob hematite ore is so dense and hard, that it is classed with magnetite for difficult reduction. The difficulty in reducing fayalite or rolling-mill cinder is to keep the silicate from fusing before the oxygen is abstracted, as a pasty silicate is formed at a low temperature, over the surface of the ore which seals up the oxygen and prevents the CO from abstracting the oxygen.

Substantially, none of the these ores exist as pure oxides of iron, but are always found in combination with one or more of the following: silica, alumina, lime, magnesia, manganese, sulphur, phosphorus, water, carbonic acid.

Fayalite varies from fifty-eight to sixty-nine per cent. of protoxide, giving about forty-five to fifty-four per cent. of iron.

Rolling-mill cinder varies from fifty-two to sixty-seven per cent. of protoxide, giving about forty to fifty-two per cent. of iron.

Magnetite varies from fifty-five to ninety-three per cent of magnetic oxide, giving about forty to sixty-eight per cent. of iron.

Hematite varies from fifty-seven to ninety-seven per cent. of sesquioxide, giving about forty to sixty-eight per cent. of iron.

Limonite varies from fifty-seven to eighty per cent. of sesquioxide, giving about forty to fifty-six per cent. of iron.

Siderite varies from forty-two to sixty per cent. of protoxide, giving about thirty-five to forty-seven per cent. of iron.

The remainder to make 100 per cent. by weight of any of the above ores, is composed of one or more of the nine substances before mentioned, in varying proportions. The earthy matters in which the ore occurs are called the gangue.

The oxygen of the ore is separated principally by carbonic oxide generated from the fuel.

The fuel may be divided into four species:

(1.) Charcoal, which is obtained by driving off by heat, the water and volatile matter from wood, leaving a residue containing about eighty-six per cent. carbon, two and one-half hydrogen, one and one-half oxygen, seven water, three-tenths ash.

(2.) Coke, which is obtained by driving off by heat the volatile matter of bituminous coal, leaving a residue containing about eighty-six per cent. carbon, two per cent. volatile matter, one per cent. sulphur, eleven per cent. ash.

(3.) Block coal, containing about fifty-six and one-half per cent. carbon, thirty-two and one-half volatile matter, eight and one-half water, two and one-half ash.

(4.) Anthracite, containing about eighty-eight per cent. carbon, three and one-half volatile matter, two-tenths per cent. sulphur, eight per cent. ash.

Charcoal is a porous, bulky material that will fire at 800°, burns away quickly, and causes a furnace charge to settle rapidly.

Coke is porous, less bulky, fires at 900°, burns moderately quick, and causes a furnace charge to settle rapidly; used with anthracite, it eases up the pressure and permits more air to pass through the furnace.

Anthracite is dense, hard, bright, gives off carbonic oxide slowly, and at a high heat is pasty and has a tendency to stick together. It burns slowly, and having no pores like coke, it burns on the surface only, requiring a large surface of contact to carburize a cubic foot of air per minute. In the blast furnace, it requires care to work alone, but with twelve to twenty-five per cent. of coke, good results are obtained. When properly handled, a pound of anthracite will do the same work as a pound of coke, but it takes more blast pressure and stronger blowing engines.

The gangue, or foreign acid elements of the ore, are liquefied by the base or bases obtained from limestone or oyster shells.

Limestone may be divided into two species:

(1.) Calcite, containing from fifty-four per cent. lime, forty-two per cent. carbonic acid, four per cent. silica, alumina and iron, to fifty per cent. lime, forty per cent. carbonic acid, and ten per cent. silica, alumina and iron.

(2.) Magnesian limestone, containing about thirty per cent. lime,

twenty per cent. magnesia, forty-six per cent. carbonic acid, and four per cent. silica, alumina and iron, to forty-four per cent. lime, five per cent. magnesia, forty-one per cent. carbonic acid, ten per cent. silica, alumina and iron.

A ton of coke or anthracite containing ninety-three per cent. carbon and two per cent. ash, is worth to the iron master, say, $3.68, while that containing seventy-five per cent. carbon and fourteen per cent. ash is worth only $2.74. An ore containing forty per cent. iron, twelve per cent. silica, is worth, say, $3.71; one containing forty per cent. iron and thirty per cent. silica is worth only $2.39. An ore containing sixty per cent iron and four per cent. silica is worth, say, $6.58. An ore containing sixty per cent. iron and ten per cent. silica is worth $6.12. A limestone containing one per cent. of silica is worth, say, fifty-four cents; a stone containing fifteen per cent. of silica is only worth fourteen cents. A furnace using forty per cent. ores with twelve per cent. of silica will make, say, 820 tons per week, but with forty per cent. ores and thirty per cent. silica will make only 500 tons. The same furnace, with sixty per cent. ores and four per cent. silica will make 1,211 tons, and with sixty per cent. ores and ten per cent. silica will make 1,039 tons. Furnace plants are in ruin to-day that have neglected to go over these matters carefully.

Oyster shells are practically pure carbonate of lime, but their use is limited to a few furnaces on the sea coasts.

The fuel is oxidized by the blast or air which is composed of twenty-three per cent. oxygen and seventy-seven per cent. nitrogen. Such are the materials used in the production of pig iron, and sound judgment must be used in their selection to make a commercial success.

The iron master having secured his supplies, selects a site for the blast furnace plant, the general arrangement of which is exhibited in *Plate I.* In making this selection, the following points have to be considered.

(1.) Transportation of the raw material to the furnace.

(2.) Transportation of the pig iron to market.

(3.) If possible, a site on competing lines of railroad.

(4.) A water supply of, say, 750 gallons per minute for each furnace.

(5.) A level plot of, say, four acres above high water, and well drained.

(6.) A cinder dump of thirty-five acres of rough land.

The size of the furnace will be governed by the fuel.

As a maximum for charcoal, say, bosh of twelve feet.

As a maximum for coke, say, bosh of twenty feet.

As a maximum for anthracite, say, bosh of seventeen feet.

Larger boshes are used but are not giving the results of smaller boshes.

The heights will be determined by the reductibility of the ores, as sufficient time must be allowed for their exposure to deoxidize them.

With siderite or carbonates fifteen hours exposure will be required.

With limonite or hydrates seventeen hours exposure is wanted.

With hematite or sesquioxide twenty hours.

With magnetite or magnetic oxide twenty-four hours.

With fayalite or rolling-mill cinder thirty hours.

These are average figures, but shorter time can be used by using more fuel. For instance, the Mount Hope Furnace made No. 1 charcoal pig with only seven hours exposure, but it used an excess of charcoal. The ore was a fine disintegrated hematite. In another instance, a furnace 13x65 feet, working with another 20x80 feet, on same stock, it was found the small furnace carried the same burden as the large one when using easily reduced ores, but with refractory ores the higher furnace carried more burden.

To determine the size of a coke furnace, the volume of air must be first determined. Say 24,000 feet per minute is used. This must have a crucible of sufficient size to use it which will be eleven feet diameter, and allowing four and one-half feet for angle of bosh on each side will give twenty feet of bosh. This crucible will consume 17,280 pounds per hour of an eighty-six per cent. carbon coke, which, with its proper burden of, say, hematite ore and limestone will take up 1,217 cubic feet of space per hour, which, multiplied by twenty hours time required for reduction, gives a furnace of 24,340 cubic feet contents, or ninety feet high.

For an anthracite furnace using, say, 18,000 feet air per minute, the crucible would be ten feet diameter, allowing for angle of bosh would give bosh seventeen feet diameter. This crucible will consume 11,514 pounds per hour of an anthracite containing eighty-eight per cent. carbon, which, with its proper burden of, say,

magnetic ore and stone, will take up 410 cubic feet, which, multiplied by twenty-four hours required for reduction, gives 9,840 feet contents, or a furnace seventy-five feet high.

The tuyere nozzles for the twenty-foot coke furnace would be eight of six inches diameter, giving a velocity of 15,000 feet per minute.

Tuyere nozzles for seventeen feet anthracite furnace would be eight to four and one-half inches diameter, giving a velocity of 20,000 feet per minute.

The angle of bosh should be 75°.

The diameter of bell equals one-half diameter of bosh, as a general rule.

The stock line at top under the bell can vary from one foot to two feet less in diameter than the bosh, according to heights above bosh.

The foundation of the furnace is built of stone, leaving in the centre an opening five feet deep, which is filled with fire-brick forming the hearth or bottom. On the foundation, are placed cast iron columns, about twenty-four feet high, on which is bolted a cast iron mantel. To this mantel is attached a heavy boiler plate jacket, extending from thence to top of furnace. On the bottom, or hearth, is placed a cast iron crucible jacket extending 18 inches below the hearth and 8 feet above hearth. This jacket has an offset in it just below the tuyere to give thicker walls to the crucible below the tuyeres, and has an opening at hearth level to draw off the iron. This jacket has one inch coils cast in it, through which water circulates to keep them cool and prevent burning of the walls. Suitable openings are left in the jacket six feet from hearths to centre for tuyeres and one 3 feet 9 inches up for the cinder notch. From the top of this crucible jacket up to the mantel, is placed a heavy wrought iron bosh jacket which is cooled by a water coil inside of it, in event of a scaffold, localizing the heat.

The crucible walls below tuyere are twenty-seven inches thick at the tuyeres, and to top of bosh the walls are eighteen inches thick, and are supported by the bosh jacket. From the top of the bosh to top of furnace, there is a single thickness of brick thirty inches long, and back of it is placed two inches of mineral wool for expansion of the brick. On the top of the furnace is placed

the wheeling plates and bell and hopper. From the top of furnace, a flue leads to the boilers and stoves to convey the gas to them for generating steam and heating blast. This flue contains numerous pockets, which catch the dust and dirt in the gas and prevents it from reaching the stoves.

The engines are generally vertical high pressure engines, but for good work at furnaces condensing engines are required. They run with a maximum piston speed of 300 feet per minute. Their piston area should be in ratio of two of steam to three of blowing piston, and they should be strong enough to blow twenty pounds per square inch when required. The boilers are plain cylinders about 40 inches diameter, say, 70 feet long, with 30-inch heaters 55 feet long under them, arranged in sets of two or three each. The stoves to heat the blast are fire-brick regenerative stoves, *Plate II*, requiring three for each furnace. They are used alternately, one on blast and two on gas. They consist of a heavy air-tight shell with a dome top, and are lined throughout with fire-brick. Inside, at front, is placed a combustion chamber over which Gothic arches are sprung. On these Gothic arches are built walls called regenerators, crossing each other at right angles, and leaving openings 9 x 9 inches vertically through them. The dome is lined with two courses of nine-inch brick.

Across the centre of the stoves, and extending from the bottom of stove up to the bottom of the dome, is a division wall to turn the current of gas and blast. On the other side of this division wall, are placed walls called regenerators 2½ inches thick, at right angles to each other, leaving openings 5 x 5 inches in them. These openings extend to within a short distance of the bottom. The thin walls are supported on girders and piers under them at the bottom. On the front of stoves are placed a water-cooled, hot-blast valve, two gas valves, and two blow-off valves. The hot blast valves are to let on and cut off the blast from the furnace. The gas valves are to let on and cut off the gas from the stoves. Two valves are used to prevent any leakage of hot blast back into the flues which fires the gas, burns the valves, and destroys the flues. Between these two valves is placed a small valve which is slightly weighted. If any blast passes the first valve, it pushes open this small valve, and escapes to the air, thereby preventing it entering the flue. The blow-off valves are to relieve the stove

from pressure when they are changed from blast to gas. They are piston valves operated by blast pressure. On turning the four-way cock attached to them, they fly open, relieving the internal pressure of the stoves, and at the same time sweeping out the dust that has been deposited in the regenerators, keeping them clean and in good order. The gas ashes or dust has the strongest affinity for the part of the stove that is the hottest, which in this stove is the Gothic arches. As all the blast sweeps quickly over them. when the blow-off valves are opened, the dust is removed each time after it is formed. These valves are then left open to admit air to burn the gas. The combination of the pockets (before mentioned) in the flue and these blow-off valves at the bottom of the combustion chamber has resulted in keeping the stoves clean for two years up to the present time. When the stoves require to be cleaned at the end of the blast, a crane swinging under the dome is used. On the back of the stoves are placed the chimney valve and cold blast valve.

With one substantial division wall in the centre of stove there is no danger of leakage through the wall by cracking and leave the gas pass direct without traversing the whole stove as occurs where more division walls are used. These division walls give but little heating surface and occupy the best part of the stove. The dome is the strongest and most substantial top for stoves, and with one division wall requires but one opening in the top, which dispenses with the skeleton walls at top where a number of openings are used. These skeleton walls are continually giving way, causing stoppages and annoyances.

To operate these stoves, gas is admitted by the gas valves, burned in the combustion chamber in contact with massive walls, escapes up through the nine-inch openings of the first regenerator into the space under the dome, thence it turns over the division wall, down through the five-inch openings, escaping through the valve at bottom to chimney. Any imperfect combustion in the combustion chamber is finished in the second combustion chamber, or space under dome. Gas in combustion expands and ascends, after combustion there is no further expansion, and, as its heat is absorbed, it contracts and descends. In the first regenerator, there is combustion and an upward current; in the second regenerator, absorption and a descending current working in

accordance with natural laws, and requiring less height of chimney. After gas has burned through a stove for four hours, the gas valves are closed, the bottom blow valves are closed, the chimney valve is closed, the cold blast valve opened, which leaves the blast into the stove. The hot blast valve is then opened, leaving the blast pass through the stove to the furnace. The next stove is then cut off from the furnace and put on gas to be heated up again. Using three stoves, gives two on gas heating up, with one on the furnace. The blast, sweeping through the stove, carries the heat absorbed by the fire-brick walls into the furnace, heating the blast 1,500° when required. This is maintained for two hours, during which time it will lose about 50° if the stoves are large enough. The escaping gas should never pass off over 350°.

Stoves with five square feet of surface in the combined regenerators to each cubic foot of air per minute will be found ample. Unless large surfaces are used, the walls glaze and lose their efficiency. All the valves are placed at the bottom of the stove, where they can always be under the eye of the stove tender, and are made so that they can be instantly taken apart and repaired. By burning more or less gas through them, the temperature can be regulated at will. The brickwork at the bottom of the combustion is massive, which retains the heat and fires the gas immediately on its entrance to the stove. This avoids the explosions which heretofore shattered the brickwork. Fire-brick stoves cannot be destroyed, they last longer, cost less for repairs, and use less gas to heat 1,600° than pipe stoves to heat 900°. In practice, it is found that taking iron pipe stoves at their ordinary limit of 900°, and replacing them with brick stoves using 1,400°, that there is a saving of fifteen per cent. in the fuel, and an increase in the make of iron amounting to twenty per cent.

Air or steam hoists are used to elevate the stock to the top of furnace from the stock house. The stock house is an iron building with two or four railroad tracks through it, which are elevated, say, sixteen to eighteen feet above the floor. It is divided off into bins for the storage of stock of different kinds, which is dumped into the bins from the cars overhead. In the stock house, at the bottom of the hoist, are placed suitable scales to weigh all the material that goes in the furnace. Strict attention has to be paid to this, as the whole operation depends on the proportions, by weight, of fuel,

ore and stone. Iron barrows are used to convey the stock from the bins to the scales, where they are balanced, sent up the hoist, and the contents dumped in the hopper. Various devices of draw bins have been tried, but the old arrangement of shovelling the stock in barrows has proved the cheapest and best. Skip hoists, to dispense with barrows going to the top, have been tried, but, so far, have not superseded the old arrangements of barrows.

In starting a furnace the first thing is to determine what the composition of the cinder shall be. A good cinder with ores not containing over one-half sulphur will be silica, thirty-eight per cent.; oxide of iron, two per cent.; oxide of manganese, five per cent.; alumina, ten per cent.; magnesia, seventeen per cent.; sulphur, two-tenths per cent.; lime, twenty-eight per cent. When there is much sulphur in the stock more lime must be used. A cinder of the following formula is good, $(2\ R_2O_3,\ 3\ Si\ O_2) + (2\ RO,\ Si\ O_2)$. Lime can replace the magnesia, and alumina replace either to a limited extent. The calculation for the cinder is made by getting all the substances in per cent. in the fuel, ore and limestone, then on separating the acids and bases, it will be found that the acids predominate. Limestone is then added to saturate the acids, giving generally two atoms of base to one of acid. Great care is necessary in selecting limestome to get it free from silica, as every pound of silica in the stone requires two pounds of lime to saturate it. A pure limestone contains but fifty-six per cent. of lime. Suppose the stone used contains fifteen per cent. of silica, then thirty per cent. of lime is required to saturate the silica in the stone, leaving only twenty-six per cent. of lime to saturate the silica in the ore. This requires more limestone, more coal, makes more cinder and less iron.

Charcoal is used in the sizes that it comes from the kiln, coke the same, averaging, say, five-inch cubes. Anthracite should be used in sizes not exceeding four-inch cubes, and ores should not exceed three-inch cubes if uniform work is wanted. Ore crushers will break the ore cheaply; it is much better and cheaper to disintegrate the ore mechanically to three-inch cubes than to depend on the furnace doing it chemically, and producing irregular iron. The dust and fine ore made by the crushers can be used by wetting it before charging it. This will allow it to get well down in the furnace before it dries. The larger, denser lumps of ore get through

the zone of fusion with greater part of their oxygen, and if not reduced by solid carbon before reaching the zone of combustion they melt, making a black scouring cinder that annoys a furnace man. Lumps of magnetite have been found at the tuyeres with their surfaces reduced in for a quarter of an inch, while the balance was magnetic oxide as put in at the top. Large ore can be used, but it is done at the expense of fuel, irregular quality, and less output of iron. Limestone should also be broken, that it may part with its carbonic acid in the upper part of the furnace before reaching a high temperature.

In the first filling of a furnace small channels are formed by loosely laid red brick on the hearth. These channels lead to the front and supply fresh air to the burning wood. The crucible is then filled with short dry wood up to the off-set or starting of the bosh, and from that point up for about two-thirds the height of the bosh is filled with coke to form a bed. Then follows a burden composed of one of coke to one-quarter of ore, and the proper amount of limestone to top of bosh, then

1	of coke	to	⅓	of ore,	etc.,	for	10 feet	up, then
1	"	"	½	"	"		15 "	"
1	"	"	1	"	"		15 "	"
1	"	"	1¼	"	"		the balance	to top.

The wood is then fired, leaving the tuyeres and iron notch open, water is turned through the tuyeres and breasts, and after six or seven hours burning the wood will be gone and cinder found trickling down the walls. The tuyere pipes are then put up, and blast heated about 500° turned on, say, about one-half the volume to be regularly used. The gas at top will fire after the wood is fired say five hours, and must be ignited to prevent an explosion. Soon as blast is turned on the bell at top is closed and the gas passes down the flue to the boilers and stoves, where it is burned for purposes already described.

After blast is on the furnace for eight or ten hours cinder will be up to the cinder notch. The iron notch is then opened and the cinder drawn off at the hearth level. This is repeated for three flushes, which cleans the hearth of the ashes and mucky cinder, heating it up and preparing it to hold a large volume of iron. The iron that flows out with these three flushes is skimmed off and sent back to the top of furnace to be re-melted. After

the third flush the cinder is drawn off at the cinder notch, and, if cinder is made rapid enough, the notch is allowed to flow constantly until next casting time, when it is closed. After eighteen to twenty hours, iron enough will have accumulated in the hearth to make a cast, when it is run out into pigs. The water is now turned through the jacket. The blast is increased as fast as the cinder will admit, which is judged of by its limpidity or flow, and the ore with its limestone is increased, judging by the grade of iron; that is, the hotter the iron the more burden can be used. The heat in the blast is held in reserve to increase or decrease the heat in the furnace as may be required.

After blast is put on, there should be no stoppage for thirty-six hours at least, when the furnace will be out of danger. The burden, volume of blast, and heat in blast, must be increased so that in six days the furnace will be up to her full capacity, as the walls and hearth will be fully saturated with heat by that time.

The furnace having started successfully, then comes the important matter of burdening her to make a given grade of iron with the least fuel. The fuel unit having been fixed at, say, 2,000, 3,000, or 4,000 pounds per charge, is never varied, but the ore and stone are varied to suit circumstances. For a general rule (but use cautiously), say, fuel contains eighty-eight per cent. carbon, 1,400 pounds fuel are required for reduction and carbonization of ores, and for each pound of cinder $\frac{31}{100}$ pounds fuel is required, which, with 1,200° to 1,300° hot blast, and not over five-tenths of one per cent. of sulphur or manganese in the burden No. 1 iron should be made, and for each grade of iron below No. 1 three per cent. less of the fuel will be required. No. 1 is a dark, large, open grain soft iron, containing about 92·40 iron, 3·50 graphitic carbon, ·13 combined carbon, 2·40 silicon, the balance being alumina, sulphur, phosphorus, manganese, etc. No. 2 is not so dark, finer grain, a little harder, tougher, and contains 93·00 iron, 3·20 graphitic carbon, ·48 combined carbon, 2·30 silicon, balance alumina, etc. No. 3 is gray color, fine grain, hard, and of high tensile strength, containing 93·66 iron, 2·32 graphitic carbon, 1·23 combined carbon, 1·94 silicon, balance alumina, etc. No. 4 is white mottled with gray spots, is harder than No. 3, of higher tensile strength and rather brittle, containing 94·25 iron, 2·10 graphitic carbon, 1·36 combined carbon, 1·30 silicon, balance alumina, etc. No. 5 is white

iron, no grain, extremely hard and brittle, containing ninety-five per cent. iron, ·36 graphitic carbon, 2·80 combined carbon. ·50 silicon, balance alumina, etc. While with all other metals their value increases with their purity, pure iron has no commercial existence, being simply a brown powder that will burn off to oxide of iron if exposed to the air. The small percentage of carbon with it is what gives its strength and value. The other elements in it change its character somewhat. Silicon softens pig iron, while sulphur and manganese harden it. Silicon and phosphorus make iron fluid or easy melting and weak, while sulphur retards its fluidity but makes it stronger.

Some furnace men sub-divide the above grades, which confuses the market. If iron will not pass strictly for a certain number put it in the grade below, which gives the iron a better standing in the market and retains customers in dull times.

Nos. 1 and 2 are foundry irons for castings.

No. 3 is used for both castings and wrought iron.

Nos. 4 and 5 are forge irons for making wrought iron.

Nos. 1, 2, and 3, when not over ·20 phosphorus, are used to make Bessemer steel.

An important subject is the proper temperature in the different portions of the furnace. All efforts to decrease the consumption of fuel and improve the working of the furnace must be based upon it.

Tracing the thermic conditions from below upwards, we have at the bottom of a blast furnace (*Plate III*), making No. 3 iron, a temperature of 2,900° F., which increases slightly to a point a little below the tuyeres. In the immediate vicinity of the tuyeres the temperature is somewhat lower, owing to the entering blast; but a short distance above the tuyeres, where all the oxygen of the blast has been converted into carbonic acid, the highest temperature in the furnace is attained. This carbonic acid is, however, almost as soon as formed, converted by the glowing coal into carbonic oxide, a process which absorbs heat, reduces the temperature, and provides the active agent for the reduction of the iron ores. In its ascent, the hot carbonic oxide gradually parts with its heat, first fusing the descending iron and earthy materials, which trickle down to the hearth of the furnace. The limit of this zone of fusion is rather sharply defined, and the temperature in this zone

suddenly decreases by the heat absorbed and made latent by the fusion. Passing on up, the carbonic oxide gas absorbs the greater part of the oxygen of the ores, forming carbonic acid, increasing the temperature, and leaving the iron reduced to a sponge. The oxide that escapes reduction by CO is then reduced by contact with solid carbon, or fuel forming CO, and causing a loss of heat compared with the reduction by CO to CO^2. In its further ascent, the hot gas drives off the carbonic acid from the limestone, which causes an additional absorption of heat, and finally the gas escapes at the top, at a temperature of about 250° F., if the furnace is working well. These changes of temperature are represented graphically, without regard to actual values, in *Plate III*[a] by dotted lines *a*, *b*.

If, now, we reverse the direction of the investigation, and trace the thermic conditions involved in the descent of the coal, ore and limestone, we find that the charges descending at the rate of about three feet per hour (if the furnace is driven properly), become heated at the expense of the ascending hot gas. At a temperature of about 570° F., the ores begin to be reduced, or to lose their oxygen under the influence of the carbonic oxide. The quantity of heat absorbed in deoxidizing the ores being less than that developed by the formation of carbonic acid, an increase in temperature is the result. Further down, at a temperature of about 750°, the limestone begins to part with its carbonic acid, a somewhat higher temperature being necessary where dolomite is used. Still descending, the point is reached where the earthy matters are fused together as cinder, and the iron separates from them. From this fusion limit downward to a point about three feet above the tuyeres, an atmosphere of carbonic oxide exists, which prevents the oxidation of the falling shots of iron, and reduces any fugitive pieces of ore which may have escaped the zone of fusion. From about three feet above the tuyeres to about six inches below them, an atmosphere of mostly carbonic acid exists. This space is called the zone of combustion, and it is upon the area of this region that the rapidity of the driving of the furnace, or the volume of entering blast, depends. From the hearth, or bottom of the furnace to the zone of fusion, the furnace is filled with glowing coal, although occasionally a stray piece of refractory ore or stone will be found here, which is reduced by contact with

solid carbon generating carbonic oxide with a loss of heat. This iron not being thoroughly carbonized mixes with the iron in the hearth and lowers its grade, by decreasing the graphitic carbon in the iron already in the hearth.

This bed of glowing coal acts as a filter or screen to take up all oxygen or carbonic acid before reaching the zone of fusion, and thereby to maintain a powerful reducing atmosphere immediately below and in the zone of fusion, as well as above it for some distance. The deoxidized ores as a sponge entering the zone of fusion with its intense heat have such a strong affinity for oxygen that they will split up any carbonic acid which may have escaped reduction in the bed of glowing coal, rob it of one atom of oxygen, the sponge burning to oxide of iron, which escapes and shows at the chimney top in a peculiar brownish-red smoke.

The heat in the hearth of a blast furnace is the result of the combustion of the fuel by the blast, to which is added, in the case of hot blast, the heat brought in with the air, and the heat brought down by the descending stock. It is evident that if the blast be cold a correspondingly larger amount of fuel must be employed to maintain the same amount of heat in the hearth than when hot blast is used. A temperature of blast of 800° F. is needed to ignite charcoal, of 900° to ignite coke, and fully 1,300° to ignite anthracite. The convenience and advantage of contributing to the heat of the hearth by heating the blast is now fully understood.

Running on a burden of one pound of coal to one pound of ore, more heat is developed than is required. The descending stock cannot absorb the large volume of heat coming up, and consequently the furnace becomes hot to the top, as shown by *Plate IV.* This excess of heat is partly absorbed by the decomposition of some of the carbonic acid in the gas by the glowing coal at the top, carbonic oxide being formed. As this amount of coal is lost to the furnace, it is wasted. This waste, however, acts advantageously by causing less coal to reach the hearth, and thus hindering the make of iron high in silicon.* This evil exists more widely than is generally supposed, as it is, to a certain extent, self-corrective. If the burden is increased, say two pounds of ore to one of

* Before the coal gets to burning at the top, in this case, iron high in silicon is always made. The excess of fuel heat on long exposure reduces the silica in the fuel.

coal, and the same volume of blast used, then the heat returned per hour to the hearth from the ore and stone will be double. This heat, in combination with a higher temperature of the blast, replaces the pound of coal which it saves, and at the same time doubles the yield of iron.

Concentration of heat at the tuyeres and in the hearth is one of the first aims for successful furnace work. This can be obtained only by large hearths, hot blast, heavy burden, and rapid driving by using a large volume of hot blast. The descending stock in the furnace collects the heat from the ascending gas and carries it down to the hearth again, increasing the intensity of combustion at the tuyeres—an important matter, when it is considered that the intensity of combustion heating the hearth determines the grade of iron.

The iron arriving at the hearth contains combined carbon but no graphitic carbon. The intense heat of the hearth changes the greater part of the combined carbon to graphitic carbon, and as the hearth is more or less hot so will the iron be grayer or whiter by the change. Buckshot iron is due to colder hearths and consequent sticky cinder which entangles the shots of iron and will not allow them to separate. It invariably accompanies sulphur, either in the ore or fuel, which requires a heavy lime cinder to take up the sulphur and avoid white iron. The more limy the cinder the higher is the heat required to fuse it.

The descent of stock in the furnace is governed entirely by the rapidity of combustion at the tuyeres. A true test of the furnace is the number of tons of fuel consumed in twenty-four hours, and the greater the proportion of ore in the burden, the larger will be the yield of iron if the furnace process is properly managed. In *Plate III*, it will be noticed the zone of reduction (colored red) is low down in the furnace compared with *Plate IV*. This prevents the CO^2 of the limestone being driven off in the presence of a high heat and combining with the fuel to waste it by forming CO near the top of the furnace as in *Plate IV*, and giving the CO no time to act on the ore. The stock entering the furnace, *Plate III*, is gradually heated, the ores well reduced at a low temperature, and there being but little excess of heat to reduce silica to silicon the resulting pig iron is low in silicon, strong and dark in color. The furnace being driven rapidly, and the heat development and heat

requirements being well balanced, the hearth is kept hot and the furnace works well. The heat that is conducted off through the foundations, crucible, bosh, shell of furnace and by waste tuyeres water is a constant sum, no matter whether the furnace makes a large or small yield. The faster the furnace is driven the hotter the hearth becomes, as the loss from the above cause is decreased in ratio to the amount of fuel cinder and iron arriving at the tuyeres and in the hearth. This allows more burden to be carried and at the same time this extra burden robs the escaping gas of more heat which is returned to the hearth, making it hotter and allowing a still further increase of burden. This cold top working favors the accumulation of cyanides, which is another economical factor to be explained hereafter.

With a furnace in normal working, it requires about one-sixth of the fuel to supply the heat lost through foundations, etc., as above explained. Taking advantage of all the little points above mentioned, and working them together as a whole, the highest type of furnace economy is attained.

A cold top and hot bottom is economy, large product and good quality. A hot top and cold bottom is waste of fuel, small product and poor quality.

Plate IV, as before stated, shows the effects of a light burden in the interior of the furnace. The amount of heat generated is in excess of its requirements and the heat gradually works up to the top. This partially corrects itself by burning off to waste part of the fuel at the top as before explained. In this case, the ores arriving in the high heat quickly, only the outside of the lumps are deoxidized when the oxide fuses with the gangue and covers the lump with a pasty coating that prevents the CO from reaching the oxygen in the interior. This ore then passes down until it reaches a heat sufficient to melt it when it is reduced by trickling down over the surface of the glowing coal, which reduces the oxygen by contact with solid fuel, forming CO with a loss of heat and making an iron high in silicon, as the more fuel the more silica there is per ton of iron in the fuel, from which the silicon is mostly derived.

To prevent this reduction of silica as much as possible with a light burden the heat in the blast has to be lowered.

Iron from a light burden is light colored, small grain, weak, but runs fluid and makes good stove castings, but costing more than

it is worth, the founder tries to get on a heavy burden and make better and cheaper iron.

When a furnace has been in blast a month, and has been worked up to full capacity, it will assume the shape given by dotted lines on drawing, *Plate III.* Starting from the tuyeres, we find, at a point just above them, that the walls are burned back, and that from there upward they are nearly uniform, until a point a short distance above the bosh is reached, when the walls are found the original thickness. This burning away is due to the intense heat. At this point, the rough, fretted surface of the walls suddenly disappear, and the walls are smooth from the wear of stock. This line between the smooth and rough surface marks the limit of the zone of fusion, and its height is determined by the volume of air entering the furnace per minute. The number of cubic feet of air entering per minute divided by five will give the cubic contents of the zone from the top of fusion limit down to the tuyeres for charcoal; divided by four, will give the cubic contents for coke, and divided by three, the cubic contents for anthracite. These figures have been determined by measuring the area spoken of and comparing it with the air entering per minute in a number of furnaces, and, for all practical purposes, it will be found correct.

Heretofore furnaces have been built with small hearths, thick walls and 80° to 85° boshes. On starting up, the size of the hearth limits the volume of air blown and the zone of fusion is found part way up on the bosh.

If sufficient heat gets above the fusion limit of a blast furnace to paste the stock and yet not fuse it, this stock jams on the bosh, as per *Plate V* forming a ring which, if the stock above cannot push it down to the fusion limit, becomes permanently set and obstructs the flow of stock. If the materials in the stock passed abruptly from the solid to the fluid state, as ice does to water, this condition of affairs could not arise, but we may rather compare the stock to wax, which, when the heat is just insufficient to melt it, becomes pasty and can then be moulded and compressed. The circumference of a furnace of twenty feet bosh is sixty-three feet, while the circumference below at the fusion limit is about forty-four feet. The stock immediately on the bosh and sliding down as a whole is about thirty inches thick, while the balance of the stock in the central portion travels independently and much more rapidly. A

compression or squeezing together of 63 — 44 = 19 feet has to take place in the stock travelling down the slope of the bosh. If the stock is pasty, it squeezes together and jams as above described. This ring or "skew-back" lodges the stock above it up to the top of the furnace (see *Plate V*). The stock descending through the middle of the furnace by its side thrust retains this lodged stock in a vertical position, making a dry wall of it. This cuts off the reducing area of the furnace and proves Cochran's law—that the yield of a furnace shows its working area.

The founder would then draw back his tuyeres, enlarge the hearth by allowing it to cut away with a larger volume of blast. This cuts away the circular ring or scaffold and allows it to come down to the tuyeres. When there was ample fuel below the scaffold from fuel blanks previously charged to meet it, the furnace would pull through all right, but, if the coal were burned away, the scaffold would chill the zone of combustion and the furnace would have to be shovelled out.

Instances have been found where a furnace 16-foot bosh, 65 feet high, had a vertical well perfectly round, 6 feet diameter, extending from 7 feet above the tuyeres to the top. The sides of the well were about 12 inches thick, composed of the fuel ore and limestone partly fused together. Between this wall and the in-walls of the furnace the stock laid loose and in good condition.

When this lodgment or scaffold occurs, the lodged part collects heat at the bottom, which accumulates and works up through it to the top of the furnace. The stock lodged against the walls under the bell becomes red hot, while the moving stock in the centre is cold. This has led to the idea that a furnace sometimes works up its walls, while the reverse is the case.

If a furnace has been in this condition for some time, the attrition of the stock and an increase of temperature sufficient to partly melt off the skew-back, sometimes causes the latter to give way slowly, and the scaffold gradually slides downward in the furnace leaving a ring adhering to the bosh. While the furnace is melting and burning up the lodged part, it becomes extremely hot, as the work of reduction has been done thoroughly and carbon is stored up in the part of the scaffold above the skew-back, where no oxygen or CO^2 can reach it. The founder in this case increases the burden and drives the furnace. As soon as this lodged part is

worked out, the furnace turns on white iron, unless the founder has reserve heat in the hot blast. When a furnace in this scaffolded condition is blown down, the dry wall around the sides falls in and no trace of it can be found. When the founder gets the furnace blown down to the bosh and finds no scaffold, he refills; but the first time slack blast is used, the skew-back builds up again and on putting on full blast the furnace makes white iron and the old trouble shows itself. From the foregoing explanations, it will be seen that the difficulty is that he did not blow it down to this ring or skew-back.*

Furnaces built the old shape, as per *Plates 5* and *6*, cut out so much at and above the tuyeres, that the engine and hot blast are not large enough to supply blast to fill this space, and the blast shuffles about from side to side of the furnace, causing it to work hot first on one side and then on the other. As the heat cannot be concentrated, white iron results. The furnace must then be blown out and a new bosh put in.

The difficulties of the old form of furnace may be avoided by adopting the form shown in *Plate III*, using a large hearth, with the proper volume of air, and placing the bosh far enough below the fusion limit to avoid the danger of the jamming of the stock on the bosh. Any pastiness of stock will occur between vertical walls, the heat will be concentrated and the blast equalized, across the tuyere section. As the upper part is simply a hopper to hold the stock during reduction, its shape will be immaterial so long as the charging apparatus can distribute the stock evenly.

If the furnace works irregular, the founder will often lay the blame on the bell and change it, thinking a smaller bell will do better, as the stock is high on the walls, but he has not discovered the fact of a ring scaffold causing the furnace to work up through the centre,

* The fuel, ore and limestone above the fused part of the ring scaffold disintegrate to a gravel and dust, which, when the ring gives way, (more or less) roll down to the tuyeres and smother the coal in the zone of combustion. The fine fuel would burn readily if the blast could penetrate it. In some few cases where the engines could blow twenty pounds to the inch pressure, they succeeded in blowing through the gravel and dust. The better plan is to take out the tuyeres and shovel it out before it fuses, sets and chills the hearth. Fifteen cart loads have been taken from a single furnace before the bright fresh coal got down to the tuyeres. A vigorous policy in blowing will stop this trouble.

and not on the sides. Let the bell alone as long as it is about one-half the bosh in diameter.

Pyrometers should be placed in the sides of the furnace above the bosh and one in the escaping flue, that the working of the furnace may be controlled in case the equilibrium is disturbed by the encroachment of one zone on another by any excess or decrease of heat. To establish and maintain this equilibrium is the work of the future. A furnace built as described will retain its shape and take a certain uniform volume of blast, as the contents of the zones of combustion and reduction will bear a fixed relation to one another. With reserve power in the stoves to correct any loss of heat, a burden of ore can then be determined upon for a given grade of iron that needs no changing, as by varying the heat of the blast to make up any deficiency or excess of heat, iron of the required quality can be always produced.

Furnaces are now built with their bosh walls well bound, water cooled, for an emergency, large hearths and blown with large volumes of blast, through short bronze tuyeres. Large hearths mean business, they must have the proper volume of hot blast and have it well distributed. To get the proper penetration and distribution of blast, the nozzles of tuyeres must be proportioned to the volume of entering air. When they are too large, the blast works up the walls, destroying them and leaving the stock in the centre to form a core. The blast then forms pockets in front of tuyeres and on slacking blast the cinder runs back in the tuyere pipe, as the cinder has no free passage to the cinder notch. To prevent this, small cinder notches are now placed under each tuyere. If too small nozzles are used, the stock on the walls settles slow by the friction and eventually forms a skew-back while the stock above is held back, forming a scaffold. When this occurs, the furnace falls off in yield.

Perfect success with the furnace depends on clean bosh walls, and the stock travelling evenly on the walls and in the centre. There must be no skew-backs on the bosh, and the blast must so penetrate that the fuel column will burn across at the tuyeres, allowing the furnace to settle evenly. But few furnaces are free from scaffolds, and it is rare to find a founder who is willing to admit he has one.

Again, if the nozzles are too large and the furnace should ease up on one side, all the blast will pass up that side, checking the

descent of the stock on the opposite side at and above the zone of fusion. If this is not corrected, the stock will fasten to the walls and form a side scaffold, as per *Plate VI*, which will show at the top by the stock settling on one side. These are the most annoying and troublesome scaffolds, and they can be often detected by their making one side of the furnace shell hot, and on going out of blast a large space will be found cut in the inwalls where the gases were forced past the edge of the scaffold, as in *Plate VI.*

A differential gauge attached to each tuyere pipe shows whether blast is entering all the tuyeres evenly. The heat under a scaffold gradually works up through it, melting out the iron and leaving behind the fuel and lime cemented together by the cinder in a compact mass. This is difficult to burn and fuse, as the blast cannot get at the fuel in it until the cinder and lime disappear. When the volume of blast is increased so that the under side of the scaffold is attacked, the skew-back will loosen more or less, and leave it down to the action of the blast, when, if there is not ample fuel before the tuyere to work it up, the zone of combustion is chilled and the furnace goes out.

The iron and cinder melting out of a scaffold is caught by the slope of the bosh, and grooves are worn in it by this running iron and cinder. If one of these grooves directs the iron and cinder on the nose of a tuyere, it destroys it, leaving water in the crucible and destroying the heat just at the time it is most wanted.

The quickest way to get rid of these scaffolds is to have a series of holes in the bosh and side walls where they are likely to form, and crack them off with giant powder, but the precaution must be taken to have some extra fuel down to the hearth to melt them up and prevent chilling. When any trouble occurs with a scaffold, the hearth generally fills up with mucky cinder, coal and iron. The iron notch should then be used exclusively to take off the cinder and iron, and if this does not clear the hearth then cut another iron notch in the crucible at hearth line opposite the regular iron notch, leaving the cinder and iron flow out there. This will heat up hearth and keep tuyeres clear of cinder. Tuyeres must be kept clear or the furnace goes out.

Heretofore, there has been a horror or dread of cutting a hole in the furnace, but this must not stand in the way of helping the furnace. A furnace with the cinder notch placed opposite the iron notch always works more evenly than with both on the same side.

When a furnace works irregularly, some tuyeres are bright, some are dark; if the belly pipe is cold no blast is entering at that tuyere and it must be opened at once by the pricker rod, or by a small cartridge exploded just beyond the tuyere, circulation must be had at once. A bright tuyere and cold belly pipe shows but little circulation. The differential gauges are the best things to rely on in this case. A constant half hourly inspection of the tuyeres must be continually made to see that no water gets in the hearth.

With a large hearth and the proper time for reduction, the faster a furnace is driven the hotter she becomes, more burden is carried, more iron made, and more steady is her working, until the limit of the volume of blast for the hearth is reached, when no further advance can be made without cooling the hearth, as the rate of combustion is limited by the size of the hearth. With a given hearth, more blast can be used at 1,400° than at 900°.

A serious evil with furnaces is a stoppage, as it always gives more or less trouble by forming incipient scaffolds. For each minute that blast is off, a furnace making 700 tons per week, 156 pounds of iron are lost. Leakage of blast is another evil to be carefully guarded against. Even with a new plant, well built, there is a loss of twenty-five per cent. of the volume when blowing ten pounds to the square inch. The volume of air that passes the tuyeres is what does the work, and not the volume that is blown by the engine. Instances have been found where the engine running twenty-four revolutions, on blanking all the tuyeres tight, the engine run sixteen revolutions on the leaks.

In addition to the difficulties mentioned of the running of the furnace, the superintendent has to be continually on the guard against changes in the character and quality of his stock, in neglect or carelessness of his men, especially at night, and in stormy weather to see that the stock is well supplied and kept dry; that freshets do not interfere with the tuyere water, and that the machinery, boilers, stoves, pumps, etc., are kept in good order.

When his furnace is carrying a good burden and a damp spell comes on, he must add fuel to the furnace to keep up his heat, as each 10,000 feet of air per minute will require a ton of coal in twenty-four hours to maintain the equilibrium of heat in the furnace. Good analysis of all stock should be going on constantly

and avoid the stumbling in the dark and the blundering of the past.

Having given a general description of furnaces, let us take up the Franklin Furnace of New York, as shown by *Plate 3*, and its workings for one week.

Hearth 9 feet, bosh 14 feet, height 70 feet, stock line 11 feet, bell 6 feet 6 inches, bosh walls 18 inches thick on slope, and 14 inches above the slope, and the mantel placed above the top of bosh. Crucible bound with cast iron water jacket. Bosh bound with heavy boiler plate jacket. Fire brick stoves.

ONE WEEK'S WORK.

Fuel per ton pig sixty-three and one-half per cent. coke, thirty-six and one-half per cent. anthracite,	2,538 pounds.
Ore per ton hematite fossiliferous,	5,091 "
Limestone,	1,426 "
Volume blast per minute in cubic feet,	13,514 "
Temperature of blast,	1,100°
Temperature of escaping gas,	210°
Iron,	614 tons.
Cinder per ton of pig iron,	2,474 "
Cubic contents of furnace in feet,	6,731
Air per minute, per 1,000 cubic feet of contents in feet,	2,000
Ratio of escaping gas by weight $\frac{CO^2}{CO}$	.938

Grade of iron, 342 tons No. 1, 260 tons No. 2, 12 tons No. 3.

ANALYSES OF ORE AND CINDER.

	Iron.	*Silica*	*Alumina.*	*Lime.*	*Magnesia.*	*Carbonic Acid.*	*Water.*	*Oxygen.*
Ore,	44·00	12·20	5·04	6·30	3·30	6·20	4·10	18·86
						Sulphur:	*Oxide of Iron.*	
Cinder,	35·98	11·80	43·67	6·38		1·12	1·02	

The ore is composed principally of small grains or shots of hematite, resembling shad eggs. This rapidly disintegrates in the furnace, leaving the CO act quickly, and as the ore contains some CO^2 this is easily expelled, leaving the ore absorb carbon quickly.

HEAT CALCULATIONS.

	Calories.
Total heat generated per ton of iron,	18,051,819
" " absorbed " "	15,661,716
Loss by radiation tuyere water, gas at top, blowing out, etc.,	2,390,103

No allowance is made for loss in expansion of blast, as this is a fallacy in the English calculations of Bell. A pound of air expanding does not lose weight and consequently cannot lose heat unless it does work. It has simply changed its quality but not its quantity. The above loss is 13·2 per cent., a gain of twenty-two per cent. in calculations of heat loss in the best English furnaces. The rapid rate of driving with heavy burden leaves the escaping gas go off at a remarkably low temperature, and prevents any burning off of the fuel at the top of the furnace by the carbonic acid of the limestone attacking the fuel and forming carbonic oxide. This low temperature of escaping gas favors the accumulation of alkaline cyanides in the furnace, which under the influence of high heat at the bottom of the absorb oxygen rapidly, and then escape upward where they part with their oxygen, are condensed on the cold down coming stock and carried down to the bosh to perform again their office of reduction, and save fuel. These cyanides are formed from minute traces of potash and soda occurring in the coke or coal, and which, being set free in the zone of fusion, escape up, are condensed on the cold stock, and returned down again. This accumulation goes on until a large volume is collected. With charcoal, there is always plenty of potash and soda. When a furnace begins to scaffold below, the stock at top gets hot, leaving the cyanides escape into the flue. If gas washers are used the waste water from washer will give off the fumes that are noticeable by their smell when the tops get hot. This simple test tells beforehand that trouble is coming.

The ratio $\frac{CO^2}{CO}$ by weight is much higher than has been heretofore found. Gas analyses are troublesome and rarely accurate as the furnace does not constantly give off a uniform volume of gas. Taking gas temperatures at the tunnel head they will vary on four points in an hour 200°. In the flue where the gas samples are taken for analyses the heavier gas, carbonic acid, flows along the bottom while the carbonic oxide flows along the top and it is impossible to get an uniform sample. This ratio of $\frac{CO^2}{CO}$ is an index or guide to show furnace men how near the gas is exhausted of its reducing power.

To absorb the last atoms of oxygen from the ores requires a high heat, especially with hard, close-grained ores difficult to

reduce. If they were reduced by CO forming CO^2 the intensely hot iron sponge would split up the CO^2 and burn part of the iron back to the oxide. This fact requires that the last atoms of oxygen must be removed by solid fuel which forms CO.

According to the degree with which reduction is carried on by solid fuel so will the ratio $\frac{CO^2}{CO}$ vary.

If perfect reduction could be made with CO the ratio $\frac{CO^2}{CO}$ would be 1·22.

The nearer we approach that figure, the less is the oxygen of the ore reduced by solid fuel. The oxygen absorbed by CO to CO^2 generates 4,205 calories while oxygen absorbed by solid fuel forming CO gives but 1,855 calories. The more oxygen absorbed by CO the more is the heat produced and the heavier is the burden that can be carried.

The less fuel burned to CO by the oxygen of the ores, the more fuel escapes to the tuyere to make CO and heat which in its turn allows more burden to be carried.

With analyses of fuel, ore and stone, gas analyses can be dispensed with by making the following calculations. Taking data from the charge book of any furnace for one week, say:

CO.	*Tons.*
Carbon in fuel (less carbon in pig) to CO., say,	5,094
Deduct CO to reduce ore, say,	1,680
CO =	3,414

CO^2.	*Tons.*
CO^2 in stone, say,	560
O in ore reduced to CO^2, say,	960
CO reduced by ore to CO^2, say,	1,680
CO^2 =	3,203

$$\frac{3{,}203\ CO^2}{3{,}414\ CO.} = \cdot 938.$$

Mr. Bell gives the best English workings at ·70, and instances have been been found at ·76. The best American practice previous to this has been ·72.

No carbon, except that in the pig, can escape the furnace except as CO or CO^2; if fuel burns off at the top, it goes off as CO, leaving that much less to burn to CO at bottom, so that the result is the same in the gas in the flues whether it burns at top or bottom. Much has been said about English workings using less than a ton of fuel to a ton of iron. While this is true, yet they have calcined carbonates, with part of the work already done, higher furnaces, and a coke that contains six per cent. more car-

bon than ours, and which will carry twelve per cent. more burden. Our ores are more siliceous and require more limestone, whose carbonic acid weakens the action of the carbonic oxide in reducing the ores, which, in its turn, to make proper reduction, requires more fuel.

At the present time, at Woodside Furnaces, in England, they are calcining the limestone, using it direct from the kilns, and find a good saving in fuel in the furnace, as the carbonic acid driven off in the kilns does not dilute the reducing gas.

By the use of rich sixty-three per cent. ores, high heat in blast, and but 608 pounds limestone to the ton of iron, American furnaces have got their fuel down to 2,020 pounds, with $\frac{CO^2}{CO}$ ·73, and escaping gas, 480°.

The limit of heat fixed by Mr. Bell in English escaping gases has been lowered by our workings beyond his expectations.

Returning to the lines of the Franklin Furnace, it will be seen that the zone of fusion is above the bosh and the bosh is below the mantel. This prevents any partly fused material touching the bosh, as all the ore and stone disappear above it, leaving nothing but the fuel to slide down the bosh, thereby preventing any accumulation on the bosh, and keeping the bosh walls perfectly clean. No water has so far been used on the bosh jacket and no signs of heat are exhibited about it. The ores are oolitic fossiliferous hematite, that disintegrate and reduce readily. This is one reason why this furnace will use so much more air per 1,000 cubic feet of contents than is usually found.

Since making the 614 tons here noted, the furnace has made 692 tons per week on the same mixture, using 14,000 feet of air per minute. Twelve years ago this furnace ten feet lower, made 156 tons per week, using the same ores—stone and fuel, but by the addition of powerful engines, boilers, and large fire-brick stoves, with an active, intelligent management, their present success has been obtained and will continue.

Turning to the Isabella Furnaces at Pittsburg, it will be found eleven years ago they averaged 578 tons per week on 7 feet 6 inch hearth, 20 feet bosh 75 feet high, to-day, with more engines and large fire-brick stoves, they are averaging 1,200 tons, while at the Lucy Furnaces 1,825 tons were made in one week on a spurt.

Heretofore, young men have kept out of furnace business, as it is a dusty, dirty, hard, brain-working trade, requiring twenty-four hours a day of constant care, 365 days a year, and as a blast usually lasts about 1,000 days, he has but little chance for a genuine holiday.

Much is yet to be learned to always operate a furnace successfully, but the day is coming when it will be run with all the precision of a Bessemer converter.

NOTE.—Mr. James Gayley, Supt. of Furnaces at Edgar Thomson Steel Works, writes, "Our furnace 'D' for week ending April 3, 1886, made 1,529 tons of No. 1 Bessemer iron, using 1,993 pounds of coke (including waste) with 65 per cent. ores and 851 pounds limestone per ton of iron."

THE NEW STAR IN ANDROMEDA.—Of all the thousands of nebulæ now known to astronomers, the Great Nebula in Andromeda is the only one, the discovery of which preceded the invention of the telescope. It was also the first upon which the telescope was turned, and it has now been a subject of observation for nearly 300 years. Yet, as a recent astronomical writer has remarked, "We are hardly more advanced than we were two centuries ago, as to the explanation of this immense nebula. Whilst, among those discovered since, some have been resolved into clusters of stars, and others have proved their chemical constitution to be of a gaseous nature, this has remained silent and mysterious. Its spectrum is continuous, without transversal lines, and consequently the substances which compose it remain unknown. The highest powers have shown some 1,500 stars in it, but it is not certain that these stars belong to it; they may simply be before it. Its shape alters strangely according to the power employed." It is premature, no doubt, to attempt to draw any very definite deductions from the present outburst; but it should always be clearly borne in mind that these "temporary" stars—this one is already fading—cannot be stars in the least resembling our own sun in size or structure. Could the radiations of our sun be suddenly increased a thousandfold, it could not possibly resume its former scale of brightness within the course of a few weeks or months. The suddenness of the increase and subsequent decrease of light prove unmistakably that we have to do with bodies relatively minute, and therefore capable of rapid cooling. The only alternative—that the star has not really altered its lustre, but that some intervening screen has been temporarily withdrawn—seems inadmissable, especially in view of the spectroscopic history of T. Coronæ and Nova Cygni. Since, then, the distance of these stars is so great (as yet an appreciable parallax has not been obtained for any one of them) and their brilliancy so high, we are compelled to substitute for a compact sun a loosely scattered, widely extending system of small bodies—a system similar in character, but on an indefinitely larger scale, to that which we see in the corona or in the rings of Saturn.—*The Observatory, October, 1885.*

HYDROGRAPHIC WORK OF THE UNITED STATES NAVY.*

By Lieut. A. B. Wyckoff, U. S. N.

[*A Lecture delivered before the* Franklin Institute, *February 19, 1886.*]

After the conclusion of the Revolutionary War, the officers of the few national vessels then in existence, were employed, as opportunity offered, in the survey of the waters of our coasts. In 1807, the President was authorized by Congress to have a survey of the coast of the United States made, and cause to be employed as many of the officers of the Navy, on the hydrography, as was compatible with the successful prosecution of the work. Under this law, and succeeding ones of the same tenor, the officers of the Navy, in times of peace, have accomplished the hydrographic survey of nearly the whole of our coasts. The resultant charts, published by the coast survey, are the finest in the world. Any careful navigator, who has them, can enter any of our principal ports with safety, without the assistance of a pilot. The officers of the Navy attached to the Coast Survey, have not been confined strictly to surveying. They have developed the beds of the Gulf of Mexico, Caribbean Sea, and Atlantic and Pacific Ocean for a considerable distance from our shores; and have spent much time and labor in the study of the Gulf Stream and the physical problems of the waters contiguous to our coasts. A present distinguished resident of this city, Rear Admiral Mullaney, spent four years in the brig "*Washington*" at this work. In July, 1885, there were sixty-seven naval officers actively employed in the Coast Survey.

The triangulation and topography of the coast line has been mostly done by civilian assistants in the Coast Survey. Their accurate scientific work is acknowledged the world over.

The vessels of our Navy have always made surveys of unknown localities abroad, whenever opportunity offered. In fact, it is one of the most important duties of our national vessels when cruising.

* This Lecture does not pretend to enter into the minute details of the scientific methods used in surveying, and was only written with the object of conveying some idea of the hydrographic work being accomplished by the United States Navy. A. B. W.

They are constantly doing a great deal of this work, as I can testify from personal experience. At different times, many men-of-war have been fitted out and sent upon special surveying cruises. In 1838, the Wilkes Expedition, consisting of several vessels, was sent to survey the South and North Pacific Oceans. During the next five years a vast amount of surveying was done, and large collections of scientific data made. The knowledge gained of the islands and coasts explored, has been of great value to commerce and the world. In 1853, a similar expedition was sent to the East Indies, under the command of the late Rear Admiral John Rodgers. It spent three years in the then little known waters of China and Japan. The commands of Page, Perry and other naval officers also did a great deal of hydrographic work.

As the result of these expeditions, 112 charts were published, besides many volumes of sailing directions and other useful knowledge.

The grand work of Lieut. Maury is probably familiar to you all. While stationed at the Naval Observatory, he was fortunate in arousing the interest and securing the assistance of all civilized maritime countries; and as the result of the observations on national vessels, and by intelligent masters of ships in the merchant service, gathered an immense amount of valuable data. This was collated and published in his sailing directions and wind and current charts. Only a seaman can fully appreciate the great importance of these publications. Ship captains were wholly guided by them, and in a few years Lieut. Maury showed, from actual data collected, that the voyage from New York to Rio Janeiro had been shortened from forty-one to thirty-four days, to San Francisco from 180 to 128 days, and to Australia from 127 to ninety-five days. These are simply taken as illustrations, as voyages between many other ports were equally reduced. When we consider the immense tonnage afloat in sailing vessels, the saving to commerce by the shortening of passages, as the result of Lieut. Maury's researches, must have amounted to many millions annually.

In 1866, Congress established the Hydrographic Office, and attached it to the Bureau of Navigation, Navy Department. Several eminent naval officers have had charge of it at different times. The present hydrographer, Commander J. R. Bartlett, U. S. N., took charge of it in 1883; and has thoroughly reorganized it, and extended its usefulness in many ways.

The law of Congress authorized the sale of the hydrographic publications at the actual cost of the printing and paper. In consequence, our charts are sold at very low prices as compared with those of foreign countries. In 1885, over 22,000 charts were printed at the Hydrographic Office. In order to preserve the original copper plates, they are now electrotyped, an alto and basso produced, and the charts printed from the latter. About 900 different charts are published, while several hundred more are issued by the Coast Survey, and 3,000 by the British Admiralty. These sheets cover the surveyed waters of the globe.

When a new rock or shoal is discovered in any part of the world, or a new buoy is placed, or light established, a notice is at once sent to our Hydrographic Office. In 1885, 2,130 of these notices, in ten different languages, were received. They were immediately translated, republished, and forwarded, with the notices of our own coasts, to our Consuls abroad, the principal newspapers, custom-houses, maritime exchanges, branch hydrographic offices, etc.

Thus the master of a vessel, about to leave port, can thoroughly post himself regarding all changes which are likely in any way to affect his voyage. The neglect of this precaution, led a consular court to severely censure a master, who came in the Capes of the Delaware recently, and lost his vessel on the shoals. Each one of these notices to mariners necessitates the correction of all the charts and sailing directions which they affect.

There is also a meteorological division of the Hydrographic Office, where the data received from our national vessels and voluntary observers in the merchant marine, are carefully collated and prepared for publication. The amount of meteorological information collected by our men-of-war, is very great. About fifty national vessels, in all parts of the world, keep extensive log books, and the data is perfectly reliable as the result of most careful observations by experienced men. The following are the data noted every hour:

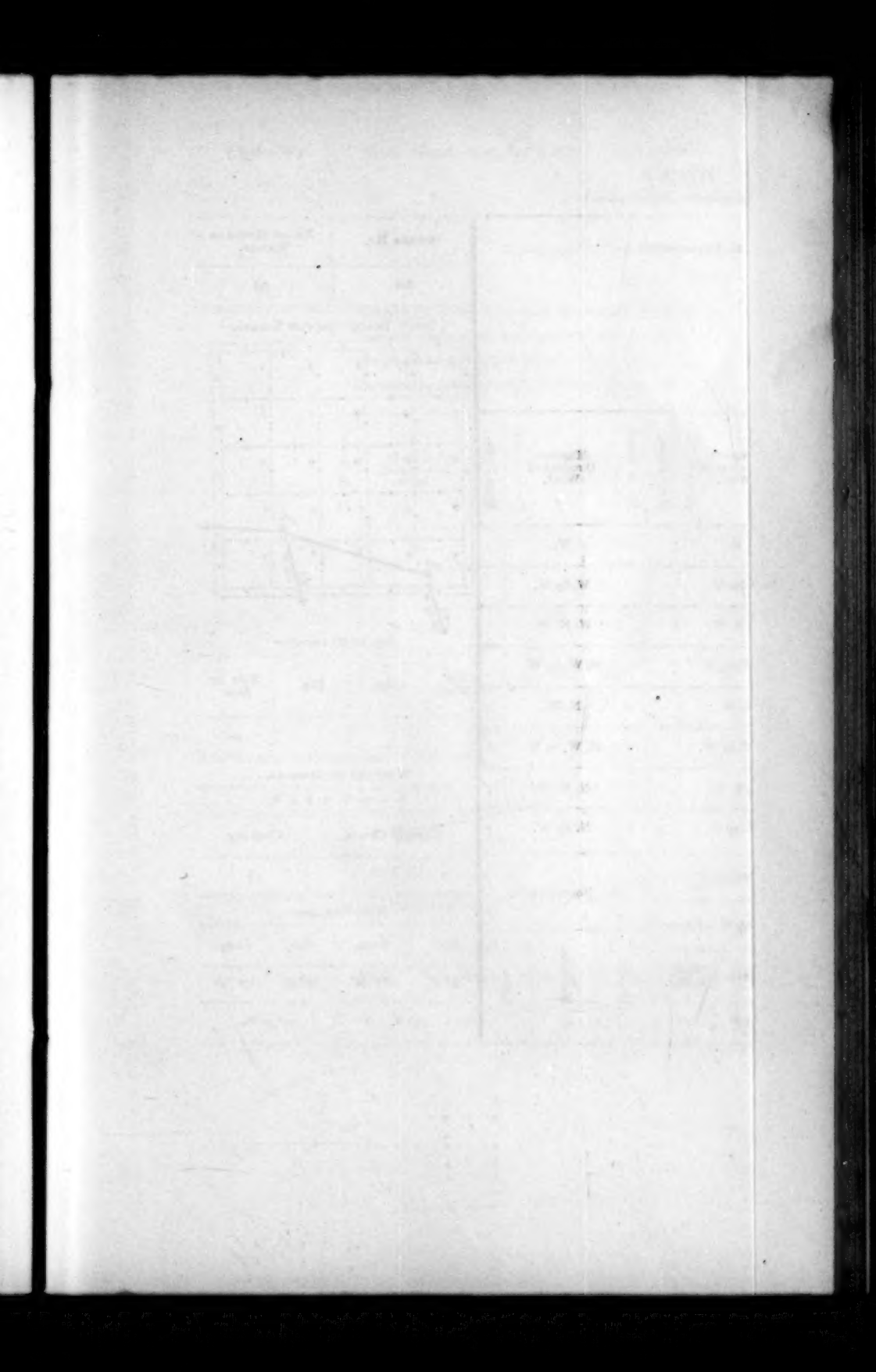
LOG OF THE UNITED STATES SHIP "*PORTSMOUTH.*"

Hour.	Knots.	Tenths.	Courses steered.	Winds. Direction.	Winds. Force.	Leeway.	Barometer. Height in Inches.	Barometer. Thermometer attached.	Temperature. Air, Dry Bulb.	Temperature. Air, Wet Bulb.	Temperature. Water at Surface.	State of Weather by Symbols.	Forms of Clouds by Symbols.	Proportion of Clear Sky in Tenths.	State of the Sea.	Record of Sail Vessel was under End of Watch.
A. M.						Pts.										
1	7	0	N. N. E.	N. W.	4	½	30·14	58	58	54	60	b. c q.	cu. nimb.	3	H.	Single reefed top-sails, fore top-mast staysail and courses.
2	6	4	"	"	4-5	"	30·12	59	59	55	60	"	"	4	"	
3	6	6	"	"	5	"	30·11	60	60	56	60	"	"	4	"	
4	7	0	N. E.	W. N. W.	6	¼	30·07	62	62	57	59	"	"	3	R.	
5	7	4	"	"	5-6	"	30 04	62	62	58	60	b. c.	"	2	"	
6	7	6	N. E. ½ E.	"	6-7	"	30·00	63	63	58	60	o. c. q. r.	nimb.	0	"	

	knots	tenths.
Distance run by Log since preceding Noon,		
Latitude by D. R. at Noon,	°	′ ″
Longitude by D. R. at Noon,	°	′ ″
Latitude by Observation at Noon,	°	′ ″
Longitude by Chronometer by Forenoon Observations,	°	′ ″
Current,	knots	tenths.
Variation of the Compass by Amplitude,	°	′
Variation of the Compass by Azimuth,	°	′

Wyckoff.

[J. F. I.,



FORM B.

(FOR METEOROLOGICAL DATA.)

HYDROGRAPHIC OFFICE, METEOROLOGICAL DEPARTMENT.

Limit of Square.

Latitude, 35° N. to 40° N.; Longitude, 130° W. to 135° W.

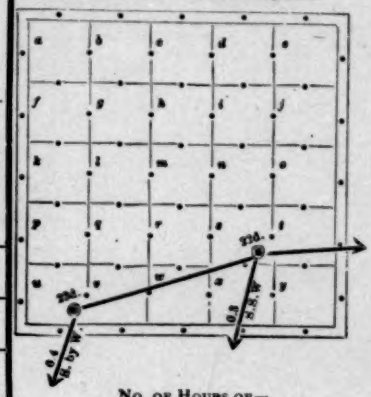
Date ship was in this square, January 22 and 23, 1876.

Compiled from the log book of the U. S. S. ——.

Commencing January 1, 1876, and ending June 30, 1876.

SQUARE NO.	NO. OF HOURS IN SQUARE.
28	40

SHIP'S TRACK THROUGH SQUARE.



No. of Hours.	Magnetic Direction of Wind.	Mean Force.	No. of Hours.	Magnetic Direction of Wind.	Mean Force.	No. of Hours.	Magnetic Direction of Wind.	Mean Force.	No. of Hours.	Magnetic Direction of Wind.	Mean Force.
	N.			E.			S.		2	W.	7
	N. by E.			E. by S.			S. by W.			W. by N.	
	N. N. E.			E S. E.			S. S. W.			W. N. W.	
	N. E. by N.			S. E. by E.			S. W. by S.			N. W. by W.	
	N. E.			S. E.			S. W.		9	N. W.	5
	N. E. by E.			S. E. by S.			S. W. by W.		13	N. W. by N.	6
	E. N. E.		2	S S. E.	1	1	W. S. W.	6	12	N N. W.	7
	E. by N.			S. by E.		2	W. by S.	7	1	N. by W.	7

NO. OF HOURS OF—

Var. Wind.	Calm.	Fog.	Rain or Mist.
			22

WEATHER BY SYMBOLS.

b. c. oc. p. q r. d. h.

Forms of Clouds.	Clear sky.
Cu. nimb.	2

MERCURIAL BAROMETER		FAHRENHEIT'S THERMOMETER.						No. HOURS SQUALLS.		
		DRY BULB.		WET BULB.		SEA W. AT SURF.				
Mean.	Daily Range.	Mean.	Daily Range.	Mean.	Daily Range.	Mean.	Daily Range.	Heavy.	Moderate.	Light.
29·91	○·26	56·4°	4·5°	52·4°	8°	60·6°	1°	13	19	

MAG. VAR. IN—

Lat.	Long.	Lat.	Long.
35° 2′	134° 30′	35° 59′	131° 36′
15° E.		14° 30′ E.	

Afternoon sights are also taken, and a great many other observations of the stars, moon, etc., are frequently made. In addition to the above, the Officer of the Deck writes up his remarks, which describe the wind and weather more fully, and notes everything of interest that has occurred; such as height and character of waves, description of peculiar clouds, meteors, water-spouts, etc. The density of the sea water is also taken at least once in each watch of four hours.

These log books are stored in Washington for future use. In order to have the meteorological data in shape for reference, the navigator is furnished with a chart, on which the navigable waters of the earth are divided into five degree squares, with a distinctive number for each. After making a passage, he carefully calculates the time when he entered and left each square. The data for each square are then collated, and entered on a blank form similar to the following, and is sent to Washington for use in compiling meteorological charts: (*See Table, Form B.*)

It is seen that the vessel was in square 28, 40 hours. The direction and mean force of wind is given for that time. The mean height and daily range of the barometer, wet and dry bulb thermometer, and sea water at surface; the number of hours of variable winds, calms, fogs, rain, and clear sky; the forms of clouds weather symbols, and the magnetic variation are all entered. In the small square to the right is shown the vessel's track, and the direction and strength of current. Appropriate remarks are appended on the form, describing the sea and weather experienced.

If the vessel should meet with a storm or cyclone, the navigator fills out a form similar to the following:

Hours.	Knots.	Courses.	Winds.	Force.	Leeway.	Mer. Bar. inches.	D. B.	W. B.	Weather.	Clouds.	Clear Sky.	Sea.
8	13	S.	S. E.	6-8	4 pts.	29·79–29·72	83	80	o. c. r.	Nimbus	0	L.
10	12	S.	S. E. by S.	7	"	29·72–58·	83	80	"	"	"	"
8	13	S. S W.	S. by E.	9	"	29·58–10·	81	79	o. q. l. r.	"	"	R.
10	13	S. W.	S. by W.	10–11	6 pts.	29·10–28·70	80	78	"	"	"	"
4	5	W.	S. W.	5-8	4 pts.	28·70–29·40	81	79	"	"	"	"

The basis of arrangement of the above form is, the changes of the wind. Remarks are added, giving a full history of the storm.

The navigator also keeps the international simultaneous meteorological observations, in which all particulars of the weather are given at 4 hrs., 8 m., A. M., 12 hrs., 8 m., and 8 hrs., 8 m., P. M., G. M. T., and the latitude and longitude of each observation.

The navigator's duties do not end with the preceding. When he enters a port, he must carefully examine his charts and sailing directions and note any changes. He must report upon the pilot, harbor and custom laws, marine signals, time signals, commerce, climate, astronomical observations, etc. When in strange waters, soundings are taken and carefully plotted; and the appearance of islands, headlands and all prominent land-marks are fully described. Some of our vessels are fitted with deep sea-sounding apparatus, and it is proposed to have them on all men-of-war, and take the depth of water, every twenty miles when making passages. Many lines of deep sea-soundings have already been run, in the Atlantic, Pacific and Indian Oceans, by the "*Narragansett*," "*Tuscarora*," "*Enterprise*," "*Gettysburg*," and other naval vessels.

Several of our men-of-war have also been provided with instruments for observations of the terrestrial magnetism, and have done much good work of this kind in foreign countries.

When a navigator enters a strange harbor, of which there is no good chart, if time allows, he is ordered to survey it. His only instruments are, usually, sextants, chronometers, compasses, a steel tape and lead lines. With these, however, a very good survey can be made. If he has good chronometers, recently rated, he can establish very accurately, the latitude and longitude of some spot near his base. Then, with his steel tape, he carefully measures his base line several times, along the level beach or some level piece of ground. The direction of his base line is accurately established by astronomical bearings. Small flags are then placed in suitable positions, around the shore line of the harbor, and the nearer ones are cut in from both ends of the base line. The signals are successively occupied, and rounds of angles taken upon the others in view. The fact that the angles of the different triangles must close within a few seconds; that is, add up 360°, is an efficient check upon the work. A permanent mark, usually a stone with a cross

cut in it, is buried at each end of the base line, and such reference is made in the notes to surrounding natural objects, as to lead to future recovery. Some prominent mark is also usually erected at the observation spot.

A large scale is adopted for a small harbor, and the base line is carefully plotted. From it, the signals are cut in upon the sheet, and the compass card constructed. The shore line between the signals is readily run in with a compass and log line, and the topography is roughly sketched. A tide gauge is erected at some spot where it is little exposed, and out of the strong currents. A staff with feet and tenths marked plainly upon it, answers perfectly well in a harbor. A permanent bench mark is erected near, and the distance, direction and height, from the plane of reference on the tide staff, carefully determined. Of course, the tidal observations should extend through one lunar month, if possible, and the plane of reference is the lowest low water. The establishment of the port, and all the tidal elements, can then be entered on the sheet. The hydrography is executed according to some general plan. The one usually adopted is to run parallel lines of soundings across the harbor, and then others perpendicular to these. If any shoal is found, it is carefully developed, and the position of all rocks and other dangers, accurately determined. The boat's crew are made to pull a regular stroke, and every minute or half minute the leadsman sounds. Every three or four soundings, the two observers take sextant angles of adjacent well-selected signals. The boat's positions are plotted on the sheet by the three-point problem, tracing paper, or a three-armed protractor being used. The latter is a graduated circle with the central arm fixed and the other two movable; and it expedites the work of plotting very much. The soundings are reduced to the plane of reference, and are spaced between the boat's positions. The character of the bottom, best anchorage, etc., is also indicated. Current observations are made, and a boat is sent outside to write up the sailing directions of the entrance. The chart is now finished. The experience of many years has led me to the conclusion that a good hydrographer is born with natural qualifications. Men of scientific ability, with fine mathematical educations, often make very poor hydrographers. Their lines of soundings are not run with judgment, their angles will not plot because of badly-selected signals, they did not understand the currents, or something else is wrong.

In surveying a large bay, a polyconic projection is used. This is easily constructed for any latitude from the printed tables. With a theodolite or transit and a plane table, extreme accuracy can be attained. Many readings of each angle are taken continuously, and the instrument reversed. The triangles must be made to close within three or four seconds, and the sides are calculated for plotting With the plane table, the topography is run in without difficulty. The telemeter is now extensively used in determining distances.

In making a reconnoissance, or running survey of a coast, it is necessary to have several good chronometers, with their errors and rates carefully determined, and a full set of astronomical instruments. A complete deviation table for the steering compass is made out, as it is depended upon for the directions of the constantly changing base line. As the vessel proceeds, frequent azimuths are taken as checks. The vessel starting from a known position steers a careful course, with a constant speed. Natural objects on shore are cut in by the sextant, or by theodolite, if the vessel is steady, and the distance of the shore line constantly determined. A continuous sketch is made of the appearance of the coast. A steam launch or launches are sounding nearer the beach, and their positions are determined frequently, especially upon each change of course. The observer in the launch can determine his distance by taking the mast head angle; and at the same instant, upon the displaying of a preconcerted signal, such as hauling down a flag, a person on the vessel takes the bearing of the launch, or an angle from her to some shore object. Both ship and launch take frequent soundings at regular intervals. Upon the approach of darkness, the vessel anchors or stands off and on, and resumes work at the same place in the morning. Every few miles, if possible, a party is landed to take astronomical observations for position, and astronomical bearings of prominent objects in both directions. If the launch discovers a harbor, a survey of it is made, as also of any reefs or off-lying dangers. To determine the contour lines of the bottom near the coast, the vessel on returning can run zigzag lines between 100 fathoms and shoal water. The chronometers are carefully re-rated at the first known position, and forward and backward interpolations made, if there has been any change. The projections are always polyconic. Such a survey as the above is

only made where there is a necessity of some knowledge for purposes of navigation. Charts, when published, are, of course, on the Mercator projection.

Naval vessels have done a great deal of work in looking for and establishing or removing from the charts, reported dangers. Very frequently merchant vessels report islands, rocks or breakers not on existing charts. A man-of-war is then sent, at the first opportunity, to examine the locality. In the North Pacific alone, there are more than 3,000 reported dangers. Frequently the same island has a half dozen positions assigned it, differing perhaps fifty miles. There is a great work to be done in the surveys of the Pacific Oceans, and the maritime nations of the world should each do their share.

Captain Joseph Skerrett, in command of the United States Ship "*Portsmouth*," removed many of these reported dangers from the charts, and surveyed others, found to exist, between 1872 and 1875.

Of recent years, naval officers, under orders from the Bureau of Navigation, have made telegraphic determinations of important points over a large part of the surface of the globe. These determinations have been made on the coasts of Spain and Portugal, the Canaries, Cape de Verdes, Uruguay, Brazil, the North and West Coasts of South America, Central America, Mexico, the West India islands, Siberia, Japan, China, the Phillippines, and joining the English system at Singapore.

The necessity of this work may be understood, when it was found that an observatory in Europe was out two miles in longitude. The accuracy of this method is simply due to the fact, that the unknown position is connected with a known position by telegraph, and the observers are thus enabled to keep a constant comparison of their chronometers. When the observers mark the stars' passage, over the wires of the instruments, upon both chronographs, nearly all the possible errors are removed.

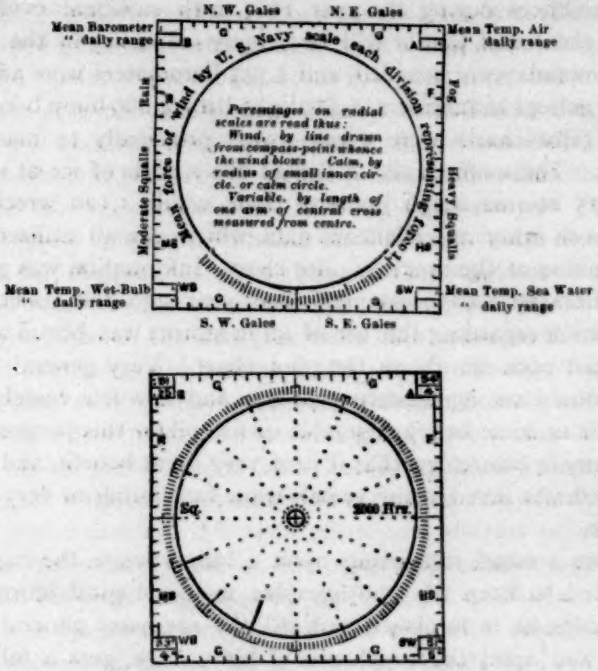
About two years since the United States Hydrographic Office established branch offices in Boston, New York, Philadelphia, Baltimore, New Orleans and San Francisco, in order to cultivate closer relations with the shipping of those ports. The Hydrographic Office had in its possession much information, valuable to the merchant marine, but there were no means of dispensing it. That office, also, desired the assistance and coöperation of merchant captains, in gathering meteorological and other data, which could be utilized

for the benefit of the mariner. Two naval officers are stationed at each branch office, and are furnished with charts and sailing directions for all parts of the world, which are kept corrected to date. They have also, for reference, a library of all kinds of nautical works. An excellent chronometer, with its error determined daily, is placed where it is accessible to the public, and a fine standard barometer and thermometer are kept for comparisons. A time-ball is dropped daily, at noon, on a staff erected where it can be seen by the shipping in port, thus enabling captains to get the error and rate of their chronometers. Every vessel is boarded upon arrival, and all the data possible is obtained from the officers and log book concerning storms, trade winds, currents, fogs, ice, water-spouts, wrecks, buoys adrift, meteors or unusual phenomena of any kind. In return, the captain is given a pilot chart and the error of his barometer, and is invited to bring his barometer and charts to the office for adjustment and correction. A captain about to leave port comes to the branch office, and obtains information about the best sailing route for his voyage, charts needed, probable winds and currents, dangers to be encountered, and knowledge of the ports he proposes to visit. Notes for the entire voyage are frequently given, and the advice is not theoretical, for it is based upon a vast amount of actual data gathered from the experience of practical men. The captain is also given the latest pilot chart, notices to mariners affecting his voyage, light lists, buoy books, and, during the cyclone period, a pamphlet upon the way to avoid circular storms. Many other monographs, upon such subjects as the magnetism of iron ships, uncertainty of fog signals, etc., have also been distributed gratuitously. A light list for the United States, contains all the lights, with full description of their character, visibility, location, height and kind of tower and buildings, etc., arranged in geographical order from Maine to Texas, and on the Pacific Coast. The buoy books, in the same manner, give full descriptions of day marks, with sailing directions for entering the ports. An American captain going on a foreign voyage, is also given the light lists of the countries he expects to visit. No other country treats the mariner as liberally in this respect as ours, and it is very gratifying to hear daily the compliments paid Uncle Sam for the interest thus manifested.

The following is some of the work of the six branch Hydro-

graphic Offices during the year 1885, with sufficient evidence to lead to the belief that it will be largely increased in the future: 11,750 vessels were boarded, and 5,343 barometers were adjusted; 16,836 notices to mariners, 1,329 light lists, 4,269 buoy books, and 15,733 pilot charts were given away, principally to masters of vessels. These offices also collected 622 reports of ice at sea, 233 fogs, 175 storms, 2,236 limits of trade winds, 1,120 wrecks, and very much other miscellaneous data, which was all utilized in the construction of the monthly pilot chart. Information was given at the offices to 10,870 people. One year ago the collection of information regarding the use of oil in storms was begun and was published each month on the pilot chart. Very general interest was aroused among sea-faring people, and now few vessels go to sea without some heavy vegetable or fish oil for this purpose. The testimony is conclusive that it is of very great benefit, and its use has no doubt saved many vessels from foundering or very serious damage.

When a vessel is starting upon a long voyage, the captain is requested to keep the hydrographic meteorological journals. If he accedes, he is furnished with all the necessary general sailing charts, and upon the conclusion of his voyage, gets a full set of meteorological charts. During 1885, 620 of these journals were placed upon vessels of all nationalities. The object is, to accumulate sufficient data, in connection with the logs of our national vessels, to construct reliable meteorological charts of all seas. A series of twelve monthly meteorological charts for the North Atlantic have been issued, and sufficient data is now in hand to complete those of the South Atlantic. The North Atlantic charts were constructed from the data of over 2,000,000 hours of observations, extending through a period of forty years. These charts, show graphically, in a form readily understood, all the phenomena in which the navigator is interested. Instead of hunting through hundreds of pages of printed matter, the master of a vessel can see at once how to lay his course, in order to secure favorable winds, and the character of weather he may expect. The ocean is divided into five degree squares, and the data are represented as seen in the following form:


N. W. Gales
N. E. Gales
Mean Barometer
" daily range
Mean Temp. Air
" daily range
U. S. Navy scale each division representing force of wind
Rain
Fog
Moderate Squalls
Heavy Squalls
Percentages on radial scales are read thus:
Wind, by line drawn from compass-point whence the wind blows. Calm, by radius of small inner circle, or calm circle.
Variable, by length of one arm of central cross measured from centre.
Mean Temp. Wet-Bulb
" daily range
Mean Temp. Sea Water
" daily range
S. W. Gales
S. E. Gales
Sq.
2000 Rms.

This form shows the true direction and mean force of the wind during the month, calms, variables, rain, fog, gales, moderate and heavy squalls, mean of the barometer, temperature of the air, wet bulb, and sea water at surface, with their mean daily ranges.

The Pilot Chart of the North Atlantic is published on the 1st of each month, and embodies all the information received during the preceding one. In the upper left hand corner is printed, all the notices to mariners, the new charts issued since the last one was published, and some of the more important reports of the use of oil. In the lower left hand corner is a storm card, showing exactly what to do under all circumstances when overtaken by a cyclone. In the lower right hand corner is a summary of the weather of the past month, and what is to be expected during the present one. The positions, with the date when they were seen, is given of all sunken and floating wrecks, buoys adrift, waterspouts, whales, and icebergs. The floating wrecks are usually abandoned in the track of vessels, and are very dangerous to navigation. When once in the Gulf Stream, they are carried towards

the coast of Ireland, and are dreaded obstacles in the path of all trans-Atlantic commerce. As they are generally only just awash, and cannot be distinguished in a fog or at night, a knowledge of their location is very essential to shipmasters. By following the reported positions of floating wrecks and buoys, a very great amount of information is obtained, of the direction and velocity of the ocean currents. As an illustration, the case of the lumber-laden schooner "*Twenty-one Friends*" may be taken. Abandoned March 24, 1885, near the Capes of Virginia, she drifted nearly in the axis of the Gulf Stream until September 13th. On September 29th, she was within 300 miles of the coast of Ireland, and on December 2, 1885, was 100 miles from Cape Finisterre, Spain. On the January pilot chart, the positions of twenty-seven different wrecks are shown, and each of them may be considered as dangerous to navigation as a rock or reef. The limits of the ice field is exceedingly important to the trans-Atlantic steamers during the spring and summer months. A safe route is laid down each month between New York and the English Channel, and the managers of steamship lines carrying passengers now require their vessels to follow it. When several steamers collided with icebergs last summer, the press of the country pointed to the fact that they had recklessly abandoned the safe route laid down on the pilot chart. I have no hesitancy in saying that I believe that much property and many lives have been saved by the knowledge of the use of oil, and the positions of icebergs and wrecks conveyed by the monthly North Atlantic Pilot Chart. In each five degree square is shown, by arrows and cross-bars, the direction and strength of prevailing winds. The limits of the trades, and the best sailing routes to and from the equator, to New York and the English Channel, are also laid down. This last information is very valuable to masters of sailing vessels, and no doubt results in materially reducing the length of passages.

Judging from the testimony of able critics, the present organization of the United States Hydrographic Office is most excellent; and it only needs liberal appropriations by Congress, to greatly extend its usefulness, and place it ahead of any similar office in the world.

The CULTIVATION of FLAX in the UNITED STATES.

By John Shinn,

Member of the Institute.

[*Read at the Stated Meeting of the* Institute, *Wednesday, March 17, 1886.*]

Col. Charles H. Banes, in the Chair.

Mr. Shinn spoke as follows:

FLAX AND LINEN.

Among the numerous fibres that contribute to the clothing and household comforts of mankind, there is no single one of greater importance than flax, which, when made into woven fabric, is known as linen.

There certainly is no material capable of textile adoption which has so wide a range, since flax furnishes a fibre suited for the finest as well as the coarsest fabric, clothing for the wealthy as well as for the poor.

Flax flourishes in all climates and soils. Egypt, in the days of the Pharaohs, extensively cultivated flax for the manufacture of linen, where it formed the raiment of the wealthy and refined portion of society while living, and was employed as the only appropriate fabric for protecting their bodies from decay after death.

Of the true history of the ancients in the days of the Pharaohs, as manufacturers of textile fabrics, we know but little, and that only by what is disclosed by the mummy pits. Mummies have been found partly wrapped in old linen shirts, napkins and other articles of domestic use. These prove the general application of linen in Egypt to all purposes of ordinary life.

Professor John Greaves, in a book published by him in 1646, speaks of the "linen shroud" of a mummy which he opened, and says: "The ribbands or fillets by what I observed were of linen; of these ribbands which I have seen some were as strong and perfect as if they had been made but yesterday."

Egyptian priests wore linen only, as it was considered the purest fabric and especially adapted for sacred purposes.

We could afford to exchange some of the ancient records we now possess of great crimes and their consequent miseries for the knowledge of one lost art.

Even the pyramids bequeathed to us by Egypt in her glory, would be well exchanged for a few of her humble workshops and factories, as they stood in the days of the Pharaohs.

From the earliest dawn of history, flax has been successfully cultivated in the hot valley of the Nile; it also thrives as well in regions so cold as those of the North of Russia, in the sixty-fifth parallel of latitude. This is owing to its rapid growth. In Russia, it is an object of cultivation only in summer and in Egypt in winter, being sown in the latter country in December and January, just as the Nile has quitted the fields. It is harvested the following April or May. In Russia, it is sown in April or May and harvested in August and September.

Judiciously managed, where the labors of the farm are not suffered to encroach one upon another, there is no single crop, which requires so little skill and attention and affords so ample a remuneration for the outlay, as flax.

Instead of the farmer dealing with the plant as heretofore, by retting, breaking and scutching, the farmer should content himself with producing the straw and seed, leaving the subsequent processes of retting, breaking and scutching to those who have special establishments for that purpose, with the necessary improved fixtures and appliances, and whose capital and skill can be more economically and successfully employed.

We now manufacture cotton, wool, worsted and silk fabrics, and carpets of all kinds equal or better than the best imported. Having the capital, skilled labor and flax as good as the best from any part of the world, why should we not make our own linen?

Although it is a fact that many tons of flax are consumed in the United States in making cordage, carpet yarns, threads and coarse cloth, we make no fine linen, such as shirting, sheeting, toilet and table linen; here, then, is the opportunity for the employment of capital, producing a *staple* article with profits as large as those of cotton, wool and worsted fabrics in their most palmy days.

Is not this the question? As the South furnishes cotton to

run the cotton mills of England, should not the West furnish the flax to run the linen mills of Dundee and Belfast?

Ireland, in 1882, had 113,502 acres in flax, yet the imports of raw flax that year in the United Kingdom were over $20,000,000 in value.

In the year 1883, Ireland had only 95,943 acres in flax, producing 18,464 tons of scutched flax, and in the same year the imports of raw flax into the United Kingdom were 77,347 tons.

The State of Illinois alone that year, 1883, had 90,000 acres in flax, and most of the straw was burned for want of a market.

The fertility of our Western lands, improvements in machinery and the energy of a free people should enable us to compete with the poorly-paid labor of Europe.

On the subject of wages and agriculture in England, Consul Shaw, in a letter to the State Department, dated at Manchester, January 5, 1885, says as follows:

"From a careful study of the cost of preparing the ground and putting in and harvesting crops in this country, I am fully satisfied that farm expenses are more than 100 per cent. dearer in many cases here than they are in America, notwithstanding the much higher wages paid with us." (See Consul's Report, No. 50, February, 1885, page 316.)

I will now produce a few facts and figures to show the quantity of imported linens required to supply our home trade, also the extent and quantity of flax now grown in this country, and that the fibres of this flax straw *now wasted*, can, by improved processes and machinery, be manufactured into linen equal if not superior to that imported.

Consul Wood, of Belfast, Ireland, in his letter to the State Department, of January 8, 1885, speaks as follows: "With regard to the entire manufactures from flax, except yarns, in Ireland, the returns show that about seventy per cent. are exported to the United States, and of the same class of manufactures from the whole United Kingdom, about fifty per cent. go to the United States. The average value of the exports for the past five years is $13,883,685."

The imports of manufactured flax into the United States from 1871 to 1881 amounted to $177,747,371, or nearly $18,000,000 per annum.

The importation of linen, in 1883, was as follows:

Brown linen under 30 cents, yard,	$10,924,649
Brown linen above 30 cents, square yard,	2,280,120
Handkerchiefs under 30 cents, yard,	488,409
Handkerchiefs above 30 cents, square yard,	585,672
Burlaps, etc.,	4,391,675
Thread, lace and insertings,	1,012,759
Thread and twine,	723,654
Other flax manufactures, N. O. P.,	814,614
Total imports of flax manufactures, 1883,	$21,221,552

It must be considered that these figures are those of the importers, and not the value for which the goods sell in the United States. It is a well known fact that importers *do not over*-value the goods imported under an *ad valorem* tariff.

The flax spinning business of Europe comprises at present 3,000,274 spindles, distributed as follows:

Ireland,	874,788
France,	500,000
Austria-Hungary,	384,908
Germany,	318,467
Belgium,	306,040
Scotland,	265,263
England and Wales,	190,808
Russia,	160,000
Total of spindles on flax at present in Europe,	3,000,274

The whole number of power looms in use in the year 1884 in Europe on all class of goods, is reported as 87,129, of which Ireland had 23,677. There are no statistics to be had of hand loom weaving, though no small amount of it is still done. It is employed to some extent in the manufacture of handkerchiefs and the finer quality of linens.

Russia is reported as having only 160,000 spindles on flax and 3,000 power looms. That country, it is stated, had in 1883, 2,000,000 acres in flax, out of a total of 3,185,074 in Europe. More than half of the flax grown in Europe is raised in Russia. It was reported that Russia in 1883, raised 250,000 tons of flax, of which 54,310 tons was sent to the United Kingdom. In 1882, Russia sent 74,489 tons. Large quantities of flax are also spun and woven by hand in Russia. In case of an extended war with Russia,

England must look elsewhere for her supplies of raw flax or else stop her linen mills.

The area devoted to flax culture in the United States in 1883, was estimated to be 1,750,000 acres, with a yield of nine and one-half bushels per acre, a total of 17,525,000 bushels, valued at nearly $20,000,000. The fibre from the straw, allowing 350 pounds of fibre to the acre (small yield) would equal 612,500,000 pounds, which at only ten cents per pound, would be valued, for fibre only, at $61,250,000.

The area of flax culture in the United States for the year 1885, I have not been able to get, but it will not be less than that of 1883; it will probably be at least 2,000,000 acres, as the demand for flax-seed to make oil, is on the increase. Linseed is quoted, July, 1885, in Chicago, at $1.24 per bushel.

The great value of linseed in the United States, for extracting oil and for making oil-cake, and also because of the exceeding worth of the fibre of the flax plant, make the crop of that plant one of the most profitable that can be raised in the Northern, Western, or Middle States.

Owing to the cost of labor in this country, it will not pay to "pull flax;" it should be cut as low down as possible by a reaper and self-binder, or a gleaner and self-binder after a reaper, which will allow the straw to dry before bundling; the straw should be well cured in the field. If it is desired to get the fibre out "long line," the seed should be threshed out by a threshing machine, such as is used on rye straw, because such a thresher takes off the seed and keeps the straw straight. "Dew retting" and steeping the flax in earth pits should be avoided, as there is no control over the elements, and out-door retting is not reliable; many lots of good flax are spoiled by cold nights and by too much rain. In the process of retting out-of-doors, no rule as to time can be given. Flax has been fully retted in five days, yet similar flax has been thirty-two days in the same pit or pond, and was even then insufficiently retted.

In Belgium, flax is sufficiently cured in the field, so that it may be held over until the following summer, when it is steeped in slow-running water while the days and nights are warm. This enables the retting, or fermentation, when once started, to continue night and day until it is ready for "grassing," which is done before the rainy season sets in.

Flax from Belgium, when the above method is practised, produces a fibre which, for its excellence, stands pre-eminent, and commands the highest market price.

An English textile paper, comparing the flax of Belgium with the flax of Ireland, speaks as follows:

"The Belgium flax, so much admired and for which so high a price is paid, has been often *nearly* approached in color and quality by odd parcels of Irish flax.

"Courtrai flax is valued on account of its 'nature,' its fineness of fibre, its evenness, and its rich creamy color. Irish flax has been known to be of almost all lengths in one field; its color is almost as variable as the districts which produce it, while it is of fair fibre, and generally possesses plenty of 'nature.' * * * * * * * If faith is to be placed in the statement that the color of the flax is owing largely to the method of steeping adopted, the variety of colors presented by Irish flax gives room for much meditation on the modes in vogue among Irish farmers, and on the necessity there is for a little more light on the subject. There is no reason to believe but that the true market value of Irish flax is obtained for it, and therefore it is all the more to be regretted that but eight shillings ($1.92) per stone (fourteen pounds) might be quoted as the average price of that fibre, while Courtrai flax can command an average of twenty shillings ($4.80) for the same quantity. It is of national importance that the quality and quantity of Irish flax should increase. In scientific and practical researches on the process of steeping lies the means of improving the quality, and this attained, an increase in quantity will follow as a matter of course."

From the above it is seen that the Irish flax brings less than fourteen cents per pound, the Belgian over twenty-seven cents, almost twice as much.

In 1883, Ireland had 95,943 acres in flax. The production of scutched or raw flax was 18,464 tons. To supply the linen mills of the United Kingdom, the imports of that year amounted to 77,347 tons of raw flax. (See Consul Wood's letter to State Department, January 8, 1885.)

If such are the wants of England, and such prices as the above can be obtained for Belgian flax, would it not pay in this country to raise flax for export? It will be said (as, indeed, it has been), that we cannot raise *good* flax in this country.

I will now give my experience on this point. I spent the last three months of 1882 at Belfast, Ireland. This entire time was devoted to collecting practical information on flax and its manufactures. Previous to this time, I had handled considerable flax, both in the straw and "scutched" state; flax that was grown in New York, New Jersey, Pennsylvania, Ohio, Indiana, Illinois and Oregon.

Some of the flax grown in New York State gave the unusally large yield of thirty-three per cent. of long line fibre from "dew retted" straw. Had this straw been properly "water retted" the fibre would have been equal both for quantity and quality to any that I saw or handled at the linen mills in Ireland, not even excepting some fancy lots from Belgium, which I was permitted to examine. I have handled flax grown in New Jersey and water retted, which, for color, lustre and strength was equal to the best Courtrai flax.

I have examined Oregon flax straw, which I found to be a superior article, giving a large yield of both seed and fibre. I have seen flax straw that was grown in Illinois, and for seed only. This straw was burned, as there was no market for the fibre, and yet this straw was as good and rich in fibre as any that I tested, which was grown in Ireland. If it had been properly water retted, it would have produced a first-class fibre.

If properly retted, all flax fibres are fine. This can be proven by any one who will take a strip of flax bark, in the green, unretted state, place it in the mouth, and, by chewing gently for a short time, the glutinous matter will be found well dissolved out (saliva being a good solvent, next to the gastric juices). The fibres will be found finely divided, perfectly white, and, while wet, easily parted by the thumbs and fingers, to any desired length.

This little experiment alone has often been the means of removing prejudice, and proving that fine linen can be made from what is called coarse flax, such as is grown for seed only, if only the straw is *properly water retted.*

The question now is, what is "retting?"

Flax straw, after the seed has been removed, *plainly* speaking, consists of three parts—sap, fibre and "boon." The only valuable part being the fibre, the sap must first be dissolved out, and this

can only be done without injury to the fibre by fermentation, after which fermentation the straw must be washed and thoroughly dried, leaving the fibre and "boon," which is removed by breaking and scutching, leaving the fibre free from the boon or shives. To get rid of the sap without injury to the fibre, color, lustre, strength and nature, is the object of steeping and retting.

Several persons, at various times, have advanced the idea that this could be done, and flax "cottonized," by putting the straw through a number of processes of steeping and boiling in solutions of caustic soda, sulphuric acid, or other chemical reagents; but all have failed, owing to the fact that the use of chemicals, and even the boiling, destroys the strength, lustre, and what the Irish call "nature of the fibre." Such was the case with Claussen's, Schenck's, Knowles', and other processes.

The writer, while in Ireland, visited a town called Dunmore to see some flax that had been so treated. The place had been fitted up, at a large outlay, with iron tanks, pipes, baskets and machinery for scutching.

The processes having proved a failure, the place was idle and the machinery for sale. There was a large lot of straw on hand that had been operated upon, which did not look bad. I went to a linen mill close by and had a conversation with the superintendent. I wanted to know the trouble. To use his words, "The flax is dead; it has no 'nature'; it will not spin." There were several tons of flax straw at the place which had been so treated, and which was for sale at any price that might be offered. It was worthless, and would not sell for tow.

In order to preserve the natural oil in the fibres (which is called the "nature") the flax straw must be kept from all corrosive alkalies, acids and boiling water.

This may be done by having the steeping tanks in a *warm* building, heating the water by steam in a *separate* tank, keeping the room warm by steam pipes around the room. This will insure a uniform heat throughout the steeping tanks, and the process of retting will not be checked by cold nights or wet days, and the process may be carried on summer and winter. The retting will be under control, and there will be no over-retting, as is often the case with dew retting, when the flax cannot be taken from the fields while wet, and it often happens that the flax is not only

"retted," but *rotten*, the natural oils in the fibre and the lustre being destroyed.

Flax straw that is uniformly water retted will scutch well, the fibres will be free from shives, and, if used for long line, will make less tow in heckling; will spin well. As most of the gum is dissolved out without loss of the "nature," the goods will bleach at less cost and have more gloss and strength than flax poorly retted.

If tangled straw, such as is grown in the West for seed, be used and run through the common grain thresher, the straw will be well and uniformly retted, the fibres of good color and strength, fine and glossy, with plenty of "nature."

The ultimate fibres of flax are short, not long, as some suppose. They are only from one to two inches long, being lapped or shingled upon each other in the progress of growth, forming long hair-like filaments, which latter many have mistaken for the ultimate fibres themselves.

Take the finest fibre of flax that is visible to the naked eye! Under a microscope each filament is a bundle of extremely fine short fibres, lapped upon each other as before stated. This can be easily demonstrated by any one who will take a thread from a *new* piece of linen, untwist the thread and moisten upon the tongue the thread or long filament. When exposed for a few minutes to the action of the saliva, the points of the short fibres may be seen starting from its whole length when gently drawn between the thumb and finger. It is a curious fact, though contrary to general belief, that these fibres are equally fine, so far as can be ascertained by the use of the microscope, whether from what appears to be fine or coarse flax. The difference between what appears to be fine and coarse flax, such as is grown for seed only, is this: in that which appears coarse, the filaments are more firmly cemented by the glutinous matter as to be separated only with some difficulty, but this may be overcome by proper water retting.

If the flax is well water retted, and free from gum, the filaments can be separated *mechanically* into short fibres, producing the long-sought "cottonized" flax; so that flax fibres may be spun into smooth fine yarn without passing the filaments through hot water.

With the spinning wheel in hand-spinning hot water is *not* used, and to show that fine spinning has been done by hand, the following is published as an account of an extraordinary feat in hand flax

spinning: "Miss Ann Macquillan, of Comber, in the County of Down, Ireland, in about the year 1815, from a parcel of flax grown in the barony of Castlereagh, spun, on a common wheel, yarn running up to sixty-four hanks, or 220,400 yards to a pound. She prepared the flax after her own peculiar system, by dividing the fibres with a fine needle."

Undoubtedly this flax was well *water retted*, and free from gum, and this flax was spun without hot water.

Many other such instances could be given where fine yarns were spun by hand, and no hot water used. We have no knowledge that the Egyptians used hot water, yet we have the knowledge that they did spin fine, smooth and strong flax yarns.

I advocate keeping the fibres and spun yarns out of boiling, or hot water, until it is made up into cloth, and then if it can be bleached without hot water, the greater and more lasting will be the lustre and strength of the fabric.

When I was in Ireland, the manufacturers in Belfast said that we could not make fine linens in America. I inquired the reason. They replied that we "had no climate." I asked, if they had one? if so, I had not seen it.

The flax spinning mills of Ireland are kept warm by steam. I was in one in December, 1882, an unusually cold day. As soon as I entered the spinning room I made the remark, "How hot!" and I noticed that the windows were opened at the top. I inquired the temperature of the room, and the superintendent, who was with me, informed me that the Government restricted the temperature to 80°, but he did not say what the temperature of the room was. I noticed that the water in the tanks of the spinning frames was quite hot, and some of them actually boiling, being heated by steam.

From this one can see that in Ireland, to enable them to spin flax the year around, they must make a climate by the aid of steam. We can do the same.

That we have no good flax grown in this country, and that we have not the proper climate to make fine linens, is nonsense.

Professor Waterhouse, of the Washington University, St. Louis, on that subject, says:

"Americans ought to surpass the rest of the world in the culture and manufacture of flax. With our wide range of latitude, the

conditions of soil, temperature and moisture best suited to the growth of this plant can easily be found. But this country ought not to be contented to raise flax merely for the sake of the seed; the largest profits are derived from the manufacture of exquisite fabrics. Consequently the attention of our farmers should be directed to the production of long line fine fibre. Our countrymen, often victorious over foreign art, need not hesitate to enter the list of competition. Surely, American ingenuity is not inferior to Irish skill. Our own mills will yet equal the woven miracles of European looms, enrich the nation with vast values, with which the creative power of skilled labor invests raw material, and retain in the United States the golden treasures which are now exported for foreign fabrics."

The late Peter Cooper, in a letter on home industry, says: "Economists justly ascribe England's wealth to its mills, indicating the time when those of Dundee and Manchester may be transferred to the valley of the Mississippi; we becoming the manufacturers and merchants of the world.

"Why wait for England's extremity, before sublimely illustrating the axiom that

Westward the course of empire takes its way."

Our country at present is just emerging from a great industrial and economical revolution; all classes of manufacturing industry were languishing, especially those of cotton and iron; yet never in the history of the country was capital so plenty and cheap. The New York City banks alone lately reported a surplus above the legal reserve of over $70,000,000.

There is no reason why we should not employ some of this surplus capital and establish a home industry in the manufacture of linens, worth at least $50,000,000 annually, giving employment to thousands, bringing the farmer and manufacturer close together, and the nearer the better? Agriculture gives to manufacturers food and raw materials; manufacturers furnish to agriculture clothing, tools and a *home market;* domestic manufacture animates and vivifies the production and interchange of commodities; without one, the other languishes and dies.

"The nation which begins by exporting only raw products of the soil, must in the end export or starve its population." They will find that their markets are too far off, and going further and

further, they will find they have lost most of the value of their crops in the cost of transportation. This is why good flax is burnt in the West, and corn is used there for fuel.

With these facts and circumstances before them, it might be well for capitalists to direct their attention to the subject, in order that they may reap the manifest advantages which may be derived from the cultivation of flax and its manufacture into linens for a home and a foreign market.

THE LAW OF CYLINDER CONDENSATION IN STEAM ENGINES.

BY L. D'AURIA.

The weight of steam condensed at each stroke of piston in the cylinder of a steam engine is intimately connected with the loss of heat sustained by the cylinder and piston masses during the period of the exhaust, and this loss is dependent upon the rate with which the cooling takes place.

Newton was the first to propose a formula for determining the rate of cooling in bodies, but Dulong and Petit, by means of accurate experiments, proved the inapplicability of Newton's formula, and taking into consideration the mass and nature of the body subjected to cooling, the extension and form of its surface, its radiating power, the temperature of the ambient, the excess of the temperature of the body on the temperature of the ambient, the nature and the pressure of the latter, they proposed the following expression for the rate of cooling, which is found very well accordant with facts, viz.:

$$u = ha^{t}\left(a^{e} - 1\right) + kp^{x}e^{y}; \qquad (1)$$

in which t, and p, are respectively the temperature and pressure of the gas with which the cooling body is in contact; e is the excess of temperature of the body on the temperature of the gas; and the remaining quantities are numbers to be determined by experience.

The first term of equation (1) on the right hand side is due exclusively to radiation; and as with reference to steam engines, the radiation of the internal surface of the cylinder is not dispersive, we can drop such term altogether, and in our case write simply

$$u = k\, p^{x} e^{y}. \qquad (2)$$

Dulong and Petit found y to remain constant for all gases and equal to 1·223; while x was found to vary from one gas to another.

For atmospheric air, ... $x = 0{\cdot}450$;
" carbonic acid, ... $x = 0{\cdot}517$;
" hydrogen, ... $x = 0{\cdot}380$.

The value of e which enters the expression (2) is given by the excess of the temperature T of initial steam on the temperature t of the exhaust, or $e = T - t$; for, the loss of heat which occurs during a single stroke is a very small fraction of the total heat contained in the mass of the cylinder, and the mean temperature of the latter at the end of stroke cannot therefore be much less than the temperature T. As to the value of p, we have to substitute for it the mean pressure of the exhaust steam.

Now the weight w of steam condensed at each stroke is proportional to the rate of cooling u (equation 2); to the mean surface Q exposed to cooling during the stroke; and to the duration of the latter $\frac{1}{N}$, N being the number of single strokes performed per minute. Hence, we can write

$$w = \frac{K\,Q}{N}\,p^{x}\,(T - t)^{1{\cdot}223}.$$

Denote by A, area of pistons; by S, the stroke; by n, the grade of expansion, and by P, the pressure of initial steam above zero. Then the weight of steam indicated up to point of cut-off (clearance included) will be proportional to

$$P\,A\,S\left(\frac{1}{n} + c\right) = \frac{P\,A\,S}{n}(1 + nc);$$

c representing clearance in fraction of stroke.

If we indicate by θ the amount of cylinder condensation expressed in fraction of the weight of steam indicated up to point of cut-off, we can put

$$\theta = \frac{K\,Q\,n}{P\,A\,S\,N(1 + n\,c)}\,p^{x}\,(T - t)^{1{\cdot}223}.$$

Represent by f the surface of steam passages at each end of the cylinder in fraction of it; and by D, the diameter of the cylinder will be

$$Q = \left(2 + f + \frac{2\,S}{D}\right);$$

and consequently

$$\theta = \frac{n\,k}{P\,S\,N(1+n\,c)}\left(2+f+\frac{2\,S}{D}\right)p^{x}(T-t)^{1\cdot223}. \qquad (3)$$

This formula applies equally to simple and compound ordinary engines; but when a duplex direct-acting pumping engine is concerned we have to take into consideration the pause which takes place at the end of each stroke, which pause is nearly equal to the duration of the stroke itself. In such case equation (3) is transformed in

$$\theta_1 = \frac{n\,k}{P\,S\,N(1+n\,c)}\left(2+f+\frac{S}{D}\right)p^{x}(T-t)^{1\cdot223}. \qquad (4)$$

Expressing temperatures in degrees Fahrenheit, and linear measures in feet, the writer has determined the values of k and x from few cases in his possession as following:

$$k = 0{\cdot}64 \quad ; \quad x = 0{\cdot}296.$$

[These values must not be considered as definitive ones, and it is to be hoped that engineers who are in possession of reliable data will not hesitate in applying them for a better determination of k and x, and make known their results.]

The above formulas can be made more handy by expressing T and t in friction of P and p. In such case we have for ordinary rotative engines

$$\theta = \frac{417{\cdot}15\,n}{P\,N\,S(1+n\,c)}\left(2+f+\frac{2\,S}{D}\right)p^{0\cdot296}\left(\sqrt[6]{P}-\sqrt[6]{p}\right)^{1\cdot223}; \qquad (5)$$

and for duplex direct-acting pumping engines

$$\theta_1 = \frac{417{\cdot}15\,n}{P\,N\,S(1+n\,c)}\left(2+f+\frac{S}{D}\right)p^{0\cdot296}\left(\sqrt[6]{P}-\sqrt[6]{p}\right)^{1\cdot223}. \qquad (6)$$

In compound direct-acting pumping engines without cut-off valves,

$$p = P\left\{\frac{r(1+c)+R}{r(r-1)(1+c)}\ \text{hyp log}\ \frac{r(1+c)+R}{1+c+R}\right\} = P\psi;$$

R being the receiver space in fraction of the volume displaced by the high pressure piston at each stroke, and r the ratio of the cylinders. Hence for the latter case we have

$$\theta_2 = \frac{P\,N\,S(1+c)}{417{\cdot}15}\left(2+f+\frac{S}{D}\right)P^{0\cdot296}\times P^{\frac{1\cdot296}{6}}\psi^{0\cdot296}\left(1-\sqrt[6]{\psi}\right)^{1\cdot223};$$

or

$$\theta_2 = \frac{417{\cdot}15}{PNS(1+c)}\left(2+f+\frac{S}{D}\right)\varphi^{0{\cdot}296} \times P^{0{\cdot}500}\left(1-\sqrt[6]{\varphi}\right)^{1{\cdot}223};$$

or

$$\theta_2 = \frac{417{\cdot}15}{NS(1+c)\sqrt{P}}\left(2+f+\frac{S}{D}\right)\varphi^{0{\cdot}296}\left(1-\sqrt[6]{\varphi}\right)^{1{\cdot}223}; \quad (7)$$

in which

$$\varphi = \frac{r(1+c)+R}{r(r-1)\ (1+c)}\ \text{hyp log}\ \frac{r(1+c)+R}{1+c+R}.$$

Examining formulas (5) and (6) it can be seen that, other things remaining the same, cylinder condensation would increase almost directly with the grade of expansion. But observing that whenever the grade of expansion n in a steam engine is increased a greater initial pressure P, is also required in order to obtain the same horse-power; it follows that the value of θ, in practice does not appear to be so much influenced by the point of cut-off as it has been stated above.

The most effective way to reduce cylinder condensation is by increasing the piston speed, which is clearly shown by the foregoing formulas.

A NEW INDUCTION IN SPECTROSCOPY.—There are reasons to suspect that the spectroscope has not told us the entire truth of gaseous nebulæ, and that solid bodies, varying greatly as to number and size, are frequently important constituents of them. Probably nebulæ vary indefinitely in the relative proportions of the solid and gaseous matter in their composition, from those which are nearly purely gaseous to those which contain scarcely anything but solid bodies. If these were exceedingly numerous, so as to overpower the gaseous spectrum of the nebula by the continuous spectrum they gave, and yet none were sufficiently large to appear as a distinct star, we should have presented to us the very features we recognize in the Andromeda nebula, and Sir John Herschel's provision, made more than half a century ago, would be realized, that "the great nebula in Andromeda may be, and not improbably is, optically nebulous owing to the *smallness* of its constituent stars. The cause of the appearance of these temporary stars still remains to be found. If we accept Denning's observations as proving that meteor-streams moving with a velocity of 200 miles a second and upwards are features of interstellar space, the passage of such a stream through a nebula might produce all the phenomena of a temporary star.—*Observatory, October, 1885.*

HISTORY OF THE ELECTRICAL ART IN THE UNITED STATES PATENT OFFICE.

By C. J. KINTNER.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January 25, 1886.*]

I once heard a member of Congress say to some of his constituents who were doing Washington City, from the tourists' standpoint: "Go first to the Smithsonian Institute where you will see all that God ever made; go thence to the Patent Office where you will see all that man ever made."

This advice, although given in jest, contained, at least so far as the Patent Office is concerned, much more truth than the speaker imagined.

The American patent system virtually dates its origin from the Constitution, in the eighth section of the first article of which our forefathers inculcated these words:

"Congress shall have the power to promote the progress of science and the useful arts by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries."

Out of this grew legislation concerning patents as early as 1790, when the first revised statutes became law.

No organized system of granting patents was developed until 1836, when the Patent Office sprang into existence, and the law was amended so as to develop substantially the system in vogue to-day. From that time to the present, just a half a century ago, there have been no material changes in the revised statutes, and there has resulted from this wise legislation the most wonderful advance in the arts and industries the civilized world ever knew.

I am invited to address you to-night, upon the historical electrical apparatus of the United States Patent Office.

You will pardon me if I broaden the scope of my remarks to such an extent as to include or make them commensurate with the growth of the electrical art as developed in and by our patent system.

In the Patent Office we recognize and protect by patent all inventions and discoveries coming under any one of the following

classifications: (1) an art; (2) a machine; (3) an article of manufacture; and (4) any improvement upon any one of the foregoing.

The limited time at my disposal will not permit me to give definitions of these statutory classifications, so I will simply indicate to you that the Patent Office recognizes about twenty-four classifications in the arts beginning with the oldest art known to man, Agriculture, following with the arts of Textiles, Metal Working, etc, and ending with the youngest and to us the most interesting—Electricity. Each of these arts is divided into classes and each class into sub-classes for the convenience of search and for the the sake of an orderly arrangement of the records in the Office.

One principal examiner has charge of each art and is supplied with from four to eight assistants, dependent upon the demands of his art.

The electrical branch of the Office prior to 1881, embraced one sub-class known as Class 36, Electricity, under the Division of Philosophical Instruments. In that year the rapid growth in the matter of electrical inventions made it necessary to make a new classification, and philosophical instruments were taken by another examiner, electricity constituting an entire class, which has since become the most important art in the Patent Office.

The introduction of the telephone, based upon Alexander Graham Bell's patent, No. 174,365, March 7, 1876, gave a new and wonderful impetus to inventions in electrical appliances. There had been, prior to that time, marked progress in telegraphs, and much ingenuity had been displayed by inventors in simplifying the methods of telegraphic communication by developing apparatus adapted for use between inexperienced operators by automatic, stylographic and printing telegraphs, but when this new and wonderful invention sprang into existence it seemed to instil new life into the inventive genius of the world. Prior to 1876, less than 2,000 patents had been granted on electrical appliances of all kinds.

So rapid has been the development that each year necessitates new classification, and a thorough reorganization of the entire classification was effected during the past year, creating in place of one class, nine, as follows:

Class 171, Generation.—Embracing all kinds of apparatus for the generation of electricity.

Class 172, Motive-Power.—Including electric motors, transmission of power, etc.

Class 173, Conductors.—Including all means of conveying electricity from point to point, and all apparatus for in any way facilitating the transmission of current without interruption.

Class 174, Medical and Surgical.—Including all applications of electricity for sanitary purposes.

Class 175, Special Applications.—Having reference to all miscellaneous applications of electricity, such as are found useful in other arts, as dyeing, tanning, machinery, etc.

Class 176, Electric Lighting.—Having reference to all uses of electricity for illuminating purposes.

Class 177, Signaling.—Including all devices used for transmitting indications or alarms and signals for specified wants or needs as burglar alarms, annunciators, railroad signals, etc.

Class 178, Telegraphs.—Including all methods and apparatus for transmitting information by codes.

Class 179, Telephony.—Embracing all appliances utilized in the transmission of articulate speech whether by electricity or mechanical telephones.

Each of these classes is again divided into sub-classes as the necessities of the case may warrant, so that under the existing classification there are found about 100 sub-classes.

Take as an example the class of telephony in which we recognize twelve sub-classes, as follows:

Telephones, calls.
" details, or attachments.
" electric,
" magneto,
" mechanical,
" radiophones,
" reed,
" relays and repeaters,
" systems, embracing central station apparatus.
" switches,
" switch-boards,
and anti-induction devices.

Each assistant examiner has charge of a definite number of subclasses of invention and he makes the examinations of all applications appertaining to the classes of invention under his immediate charge. The principal examiner has charge of the entire

art and supervises and passes upon all matters appertaining to the granting of patents in his particular art.

As at present organized, the force of the electrical division embraces one principal examiner, eight assistant examiners, three clerks and one stenographer. Some idea may be had of the amount of work done by this force by examining my late annual report to the Commissioner of Patents, from which I note that there were filed, during the year, 2,019 new applications; there were filed 3,679 amendments calling up old or rejected cases for further action. There were granted 1,320 patents, there were made 6,036 actions upon all kinds of cases, and there were abandoned by act of law 610 allowed cases.

With this very brief insight into the general method of doing business in the Patent Office, we are prepared to review the art from its earliest inception.

It is a remarkably strange fact that in this, the youngest of the industrial arts recognized in the Patent Office, very few of the earlier inventions which note great advances were ever patented in this country.

We find that many of the very best batteries known in the art were the result of laboratory experiments made by such physicists as Grove, Bunsen and Daniel, and were never made the subject of patents in America.

So, too, with the earlier friction generators; the broad principle of reactionary generators discovered by Hjorth, and the broad idea of the division of the arc light as developed by Messrs. Lacassagne and Thiers as early as 1856.

We note also that Starr King, of Cincinnati, O., took English patents for the broad idea of an incandescent lamp with continuous conductor in an exhausted globe, as early as 1845, but never patented in America.

It seems remarkably strange that this should be true, and I can only attribute as a reason that it is a generally acknowledged fact that men of science seldom patent their discoveries.

Many of the best inventions made known to the world have been donated by men of science to the public, and apparently for the reason that the scientist seems to be so deeply engrossed in his labor of love to which he devotes his whole soul, that he cares for little else than the gratification which his researches bring to him and his fellow-laborer.

It is particularly gratifying to us that this mysterious art comes within the domain of the scientist, and that such scholars as Faraday, and Ohm, and Ampère, and Varley, and Thomson, and Clerk Maxwell, and a host of others were and are its acknowledged patrons.

In treating a subject relating to the history of an art extending over a period of half a century, and embracing a matter of 10,000 patents, I can, of course, only touch here and there upon such matters to-night as note matters of interest or marked steps in the art, and I will note the progress chronologically, rather than by assuming to discuss any particular phase of the art extending through that period of time.

The records of the Patent Office show that the first patent disclosing any electrical appliance whatever was granted in 1833, July 22d, to D. Harrington, of Philadelphia, Pa., for an apparatus for curing diseases by electricity.

Strangely enough, we here find a native of the dear old city of Brotherly Love at the very threshold of an art displaying that commendable spirit of philanthropy for which her citizens have been noted since the days of Penn, and seeking by this new and wondrous art to extend the hand of brotherly love to a suffering companion.

However commendable the inspiration may have been which led Mr. Harrington to thus offer aid to his suffering fellow-men, I cannot vouch for the efficiency of his apparatus, which consisted in applying two metals of different electrical potential to the body in such manner as to generate an electrical current through the body.

I am of the opinion that no very gratifying results would be attained from its use unless it be assumed, as is often the case with this class of inventions, that the patient is to be blessed with a very large endowment of faith.

Mr. Harrington took out two more patents on apparatus of a similar nature in the following years 1834 and 1835.

These three patents are all that are found upon the records in the art prior to the establishment of the Patent Office proper in 1836. The original records of them were destroyed in the great Patent Office fire of 1836.

The first patent granted under the revised law of 1836, was to

Thomas Davenport, of Brandon, Vt., for an electro-motor on the 25th of February, 1837.

The motor is a curious relic, and although meagrely described, I will endeavor to give you a clear understanding of it, obtained from a study of the model and the specification.

The armature consisted of four axial magnets attached to a wooden wheel supported by a vertical shaft.

The winding of these magnets was continuous from one to the other, and the commutator brushes had their bearing on segmental strips, equal in number to the number of electro-magnets.

The field magnets, two in number, were arranged concentrically about the armature, and were composed of permanent magnets. It was not dissimilar in its action to the well-known Gramme machine.

On the 27th of June, 1838, the first derived circuit motor was patented to N. Walkly, of Tuscaloosa, Ala.

This motor, like that of Davenport's had an armature with axial magnets attached to a vertical shaft. The current was reversed through the armature at each half revolution by an eccentric and commutator springs analogous in their operation to the valve mechanism of a steam engine.

The field magnets were energized by a derived circuit flowing always in the same direction from the battery.

It possessed many remarkable features found in the best types of electric-motors of to-day, and probably failed in its efficiency only because of its clumsy commutator action.

Following closely upon the heels of the Walkly motor, came the Stimpson motor, patented on September 12, 1838. It is not dissimilar in its general appearance to the well-known Alliance magneto machine, and consists of an armature composed of a series of magnets arranged parallel to the revolving shaft which carries them, and so that both poles of these magnets shall be exposed to opposing field magnets located in planes parallel to their ends and radially fixed with relation to the revolving axis. The commutators were arranged in a manner not unlike the well-known Gramme commutators, and the current was commuted through the armature magnets successively as they came into the effective field of the field magnets which were charged by an additional battery.

At this stage of the history of the art, there comes upon the scene of action the first inventor of lightning rods who seems to

have availed himself of the protection offered inventors by our patent system. Whatever may have been the merits of his invention, and whatever success he may have attained with his patent, there can be no question but that he, Joseph S. Barber, of Glouces-ter, Mass., deserves at least a passing mention in order that the rural communities of this great country may know to whom they are primarily indebted for the annual precipitation of lightning rod literature and persuasive eloquence in behalf of an assured protection from the ravages of one of Nature's most destructive elements.

This, the first patent upon lightning rods, was granted March 6, 1839, and to one versed in the peculiarities of statical electricity, the invention covered by it appears somewhat peculiar, and I may add, to be of doubtful utility. It consisted of a paraboloidal metal body, having its base attached to a wooden rod, the latter fixed at some elevated position above the structure to be protected.

Affixed to this paraboloidal body were several sharp points of metal projecting in all directions about it.

The inventor assumed that when a storm cloud approached, this metal shield would cause the bound electricity in the structure to be disseminated before the cloud reached a striking distance.

I do not know if the inventor ever located himself in a building so protected or, perhaps, I should say so exposed. Inasmuch as nothing is known of his future success, and the records show nothing more in his direct line of invention, I take it that it is entirely probable he did try it and with such a gratifying result to the public as might readily be expected, viz., total annihilation.

It is pretty generally assumed on the part of our countrymen that Prof. Morse was the first to patent the electric telegraph in this country.

This is a mistaken notion, as the records of the Patent Office show that Messrs. Wheatstone and Cook, of England, took a patent for their needle electro-magnetic telegraph on the tenth day of June, 1840, while Prof. Morse's patent followed only ten days later.

The Wheatstone and Cook needle apparatus consisted of several wires running to the distant or receiving station, in each of which was located a galvanometer adapted on closure of the circuit to cause a needle to vibrate to the right or left as desired.

It was necessarily cumbersome and never found a place among

the practical inventions of the art in this country. It stands upon the records only as one link in a chain of historical apparatus.

This patent also embraces some features upon underground conduits, which are of general interest at present in view of the attempts to force conductors under ground.

It was primarily to Morse's apparatus based upon his code of signaling and the use of a single line wire with his well-known recorder that we owe success in telegraphy. So well known is Prof. Morse's invention that it is not necessary to offer any description here, but simply to note that the original models on file in the Patent Office take the first rank among such historical curiosities as the Howe sewing machine, the Jacquard loom, etc., etc.

It is very curious to note also that the models made by Prof. Morse are marvels of workmanship and proportion when we consider the fact that he was pioneer in the art, and labored under difficulties known only to a great inventor struggling against fate.

In 1842, March 28th, the first patent was granted to Patrick Coad, of Philadelphia, Pa., for an improved galvanic battery for medical uses.

It appears as though the early history of the art looked entirely to your city for those men of genius who should devote their efforts in behalf of the afflicted. This invention notes only an improved manner of immersing the plates of a battery in a cell so as to indicate the quantity of current and also an improvement upon the electrodes used by the patient.

It is of no especial importance other than being the first galvanic battery protected by patent in America.

In 1846, April 11th, we find the first printing telegraph patent granted to Royal E. House.

It consisted of a key-board having keys controlling the rotation of a power impelled cylinder which in turn controlled the operation of a circuit breaker in the telegraph line, extending to a distant receiving station where was located a power impelled type wheel controlled by an electro-magnetic escapement.

This application, which was the parent of a large class of inventions known as printing telegraphs, was followed in 1848, December 5th, by Bain's automatic telegraph which was destined to avoid the Morse patent heretofore referred to It operated by or through the agency of an electrical current acting upon a circuit upon a paper

made sensitive by a chemical solution. Out of this patent grew the famous suit, O'Reilly *vs.* Morse, in which the Supreme Court of the United States held Morse's eighth claim, which was in effect to the use of electricity for the transmission of intelligence, to be void.

The first patent upon a straight current magneto-electric machine bears date of November 1, 1853, and was granted to Calvin Carpenter, of Pawtucket, Mass. It is substantially an Alliance machine with commutator arrangement for staightening or directing the current; the armature consists of a series of electro-magnets whose cores are exposed at both ends to the influence of permanent magnets arranged in front of them. The commutation of current is not substantially different from that in general use on this type of machines as now used.

I will now call your attention to the Page motor, patented by Prof. Chas. G. Page, on the 21st of January, 1854. In this motor the two armatures consist of long cores of iron which are adapted to slide with an oscillatory motion through two pairs of solenoids made up of successive sections which are brought into action by sliding commutators actuated by rods from eccentrics on the fly-wheel shaft, being entirely analogous to the cut-off mechanism used in a steam engine.

It was not, however, a practical motor, nor is any motor, so far as I can ascertain, which depends for its action upon shifting commutators actuated by eccentrics, for the reason that the element of friction is above the mean.

This motor is the more interesting to us because its inventor was an acknowledged authority in electrical matters in his day, was the associate of Prof. Henry, and the discoverer of what is known as the Page effect in the cores of electro-magnets. He was also one of the first examiners appointed in the United States Patent Office under the law of 1836.

On the 18th day of May, 1858, Messrs. Collier and Baker took out the first patent granted by the United States for an improvement in the arc light.

It consisted of two electrodes of carbon; the upper carbon was prevented from contact with the lower by a retaining diaphragm of metal through which its point projected.

It acted by a mercurial feed, the carbons being forced forward

by the mercury in which they were immersed. As a practical lamp, it was not a success.

By a strange coincidence during the same year the first patent upon an incandescent lamp was issued to Gardner and Blossom, composed of a platinum coil enclosed in a glass chamber, but this containing chamber was not exhausted.

This lamp was of course not practical. This year was also productive of the first successful duplex telegraph, invented by M. G. Farmer, and also what is known in the art as the Hicks telegraph repeater for transferring messages to successive lines.

In 1859, on the 20th of September, the well known Grenet battery was patented.

On the 26th of February, 1861, there was patented to Charles Kirchoff, of New York, an improvement in storage batteries which deserves special mention here. It stands out alone to-day as an invention at least twenty years in advance of its time, and the description and model are wonders of curiosity to those dealing with the question of storage batteries.

I venture to say that no one of the older patents in the art has been more generally quoted and appeared in the light of an annoying reference to those who imagined they were original inventors than the one under discussion

It is of the Planté type, composed of lead plates adapted to be charged as was Planté's battery. Kirchoff saw the necessity of increased surface for his electrodes and to this end proposed many forms consisting of corrugated plates, wire netting, perforated plates, etc. He well understood the necessities of the case and his specification discloses a knowledge of the art at once as wonderful as was his ingenuity in developing means of overcoming to him known difficulties.

He also developed an apparatus for charging each cell in succession while the charged cells were discharging upon an exterior working circuit.

I regret that I have not the model with me to show you the wonderful genius of an inventor who was developing an art destined to sleep nearly twenty years.

The next improvement in this line of invention was patented to C. G. Percival, of Brooklyn, N. Y., on November 9, 1866. It consisted of a wooden battery cell divided into two chambers by a

porous partition. In these chambers was placed powdered carbon or lead in such manner as to surround the electrodes.

This carbon or lead was saturated with dilute sulphuric acid, after which it was ready to receive the charge. This is the first storage battery having active material surrounding the electrodes.

On the 23d of April, 1867, a patent was issued to G. S. Leclanché for the famous battery now found with slight change in almost every telephone box in the land. It is too well known to need description here and stands as a land-mark in the list of useful inventions covered by patents.

I come now to an important invention by Prof. Page, covered by patent No. 76,654, April 14, 1868, and afterwards reissued on the 10th of October, 1871, by Prof. Page's assignees, the Western Union Telegraph Company, in such broad terms as to include all telegraphic apparatus wherein a main circuit is caused to operate or control a local circuit, and also the use of a retractile spring to an armature of an electro-magnet.

This is the famous Page patent, so long held by the Western Union Telegraph Company as a menace over the heads of other telegraphic corporations.

It consisted of the well-known form of induction apparatus with an automatic circuit breaker, and was invented by Prof. Page many years before he took a patent which was granted by virtue of a special act of Congress, he being an officer of the United States Patent Office, and therefore disqualified by law to take an interest in any United States patent except by inheritance or bequest.

This patent expired April 14, 1885, and thereby opened wide a great field, although it is extremely questionable if the reissue could have been sustained in its broadened aspect in view of modern Supreme Court decisions touching the question of broadened reissue patents.

We now note the appearance of the first double type wheel printing telegraph, patented to E. A. Calahan, April 21, 1868, and reissued to the Gold and Stock Telegraph Company, on the 25th of July, 1870.

This instrument was the first to utilize double type wheels, one of which printed letters and the other figures.

It has since passed into the hands of the Western Union Telegraph Company, and suit is now pending between said company

and local printing telegraph companies in New York City for infringement of its claims.

An interesting invention is found in a patent to two Frenchmen, Messrs. Chauvassaignes and Lambrigot, bearing date of July 28, 1868, wherein the message to be transmitted was marked in non-conducting ink upon a metallic tape designed to act as a transmitter by which the circuit of a telegraph line was broken and closed, and the message was recorded upon sensitized paper at the receiving station. Inasmuch as the rapid telegraph companies are using this invention as embodied in more improved apparatus to-day, this invention notes an early stage in an art then quite undeveloped.

I desire now to call your attention to an invention by one whose name appears for the first time upon the Patent Office records on the first of June, 1869. It is a patent for a vote recorder. This was Thomas A. Edison's maiden patent, and is a device for recording the ayes and noes of a voting assembly. Two circuit closers are located at each voter's desk, and connect from the battery with two indicators, one for the ayes and the other for the noes. In the same circuit is a metal cylinder covered with chemically prepared paper and adapted, when a circuit is closed at a voter's desk, to print either aye or no as desired. As the vote progresses, the cylinder is rotated and each voter's vote is silently recorded, the indicators at the same time checking the total vote. Since this patent was granted, Mr. Edison has taken over 150 patents, and I think I do not overestimate his abilities when I say that no other inventor has done so much to advance the entire art as has he.

Upon looking over his list of patents I find him accredited with no less than forty-five patents upon printing telegraphs alone, many of which are in daily use in our stock exchanges.

The gravity battery of Jean Armand Callaud, deserves a passing mention, and was patented October 17, 1871. It, like the Leclanché battery, is of such general public notoriety as to need no description here, and is perhaps in more general public use than all other kinds of batteries combined. It marks an important era in the art, in being one of the cheapest and most efficient of battery generators.

A passing mention must be noted here of the Gramme dynamo machine, patented October 17, 1871, which is the first ring arma-

ture generator patented in America. Its construction is too well known to need description at my hands. The patent has expired by limitation of a foreign patent, and the invention is now public property. The Wilde machine, so well known in the art as the first dynamo with field magnets excited from an extraneous circuit, was patented in the year 1866, November 13th, and is now public property also.

We come now to an interesting invention in the patent of J. B. Stearns, 126,847, May 14, 1872, for overcoming statical disturbances on long duplex lines by the use of condensers. Prior to this invention it was not possible to transmit accurately two or more messages on existing duplexes over distances exceeding from thirty to fifty miles. Mr. Stearns conceived the idea of giving to the artificial line of a duplex telegraph an artificial electro-static capacity which should equal that of the main or direct line. This he did by inserting adjustable condensers in a branch of the artificial line, and adjusting them until no false signals occurred. This was the first great step in successful long distance telegraphy. The patent has since been reissued by the Western Union Telegraph Company, Mr. Stearn's assignees, and suit has recently been brought under the reissue against the Baltimore and Ohio Telegraph Company, in New York. The patents are very valuable if they shall be sustained.

An invention, which is of special interest from an historical standpoint, is found in the patent to E. W. Siemens of April 14, 1874, which discloses the first unipolar magneto machine covered by patent in this country. It is so constructed that one pole of the field magnet lies within or is surrounded by the other pole, the armature being arranged to revolve or vibrate in the intervening field.

We now come to a dynamo which has peculiar interest at this time because it is the parent machine patented in America, which depends upon the now well-known reactionary principle found in many of the better forms of dynamos in use to-day. It was patented to Moses G. Farmer, April 13, 1875, and is not dissimilar in its general construction, to the series wound reactionary dynamos now found in public use. Although Mr. Farmer obtained a broad claim for the reactionary principle, it has since been discovered that Hjorth, Pacinotti, Siemens and others had patented and described, this applied principle in Europe as early as, and even earlier than

1870, so that this patent merely stands upon the record as being the first to claim an applied principle, which has since received such general and wide-spread application.

It is a remarkable fact that by a strange chain of coincidences many of the leading and essential features embodied in successful incandescent and arc lighting, and also in dynamo machines to-day are public property. It is only upon comparatively limited patents that existing light corporations are based, and this rightly by virtue of abandonment or public use on the part of the original inventors of these broad features.

The advent of the year 1876, the One Hundredth Anniversary of our National Independence, seems to stand out in bold relief as a year of progress in the electrical art.

Prior to the first of January of this year, the Patent Office records note, all told, 1,923 patents.

On the 7th of March, 1876, a patent was issued to Alexander Graham Bell for a speaking telephone, which gave a new impetus to invention and at once gave to the world an increased idea of the importance to be attached to that wonderful, intangible element—electricity.

From that date to the present, I cannot undertake to consider as I have in the foregoing remarks what individual inventions have been realized, and cannot even hope to give you a faint idea of what is disclosed in the 8,000 patents granted in less than ten years —more than four times the number previously granted in a period of nearly a half century.

In 1877, came Brush with his well-known dynamo and his improvements upon arc lamps, followed by Weston, Hefner-Alteneck, Thomson and Houston, and a host of others, until the list of inventors becomes almost legion.

You are all, I doubt not, quite as familiar with the existing state of the art disclosed by well-known apparatus in general public use, as am I, since the apparatus in such general use is but a copy of that disclosed by the Patent Office. Telephony has grown from the parent patent of Bell to include more than 500 patents; arc lights as many more, and incandescent lights and fixtures a like number.

Whole new classes of invention have grown up in the period of less than ten years, until as they multiply we are forced to ask when and where will this march of genius cease.

Capital has kept pace with this wondrous exposition of ingenuity and finds itself ever ready to exploit and put in public use the inventions spread upon our records until it has become almost an axiom that to patent an electrical device seems to assure the inventor at least some revenue for his pains.

Amid all this clamor for investment in this mysterious field, the patent sharp has not been idle, and I regret to say that many capitalists have met with sad reverses because of investments in worthless patents, or perhaps I should say, worthless inventions based upon patents.

It is a matter of deep regret that this is true, for a few such unlucky investments do vastly more damage than one can estimate, by frightening away available capital from commendable inventions. However this may be, I cannot express much sympathy for any man who will invest his capital without first ascertaining the probabilities of successful return.

One such a success as Prof. Bell's patent stands out as a Mecca of hope, towards which all avaricious eyes are turned and with a greed for gain which causes unfortunate investors to be swept into veritable maelstrom of distress. Such princely incomes as it has been Prof. Bell's and Mr. Brush's good fortune to attain, do not often fall to the lot of man, but rather tend to lure one on in the hope of some time reaching the goal of success.

I have sought in the preceding remarks to give you the written history as briefly as possible, of the electrical art as we find it outlined upon Patent Office records, taking here and there as landmarks some leading or interesting patent and tracing thus step by step its progress to the Centennial year believing you to possess, as do most of our newspaper reading communities, a general information of the general history of the art from 1876 forward. So much interest is now displayed in electrical matters, and so many are the facilities for attaining knowledge in that direction, that little need be said of the present history of the art, either in or out of the American Patent Office.

Every one who reads is familiar with the modern quadruplex by which four messages are sent simultaneously over a single wire —the invention of Messrs Nicholson and Edison.

The multiple synchronous telegraph of Delany was exhibited at your famous electrical exposition in 1884, as were indeed, thousands

of other interesting and important inventions which go to make up the more modern history of the art. These you saw, and learned by actual practical application of all the more important apparatus patented during the last decade.

I cannot close my remarks without saying something of the unwritten history of this wonderful art in the Patent Office, a history known only to the employés of the Office and oftentimes intensely interesting.

To you and to every one the published records of the Patent Office are open and he who runs may read.

No one but an examiner of the Patent Office, and particularly an examiner in the Electrical Division, can form any conception of the wonderful workings of the human mind. It is to him that the most wonderful (?) inventions are unburdened, and he is forced to wrestle with electrical problems which would almost cause Faraday and Ampère to turn in their graves! It is true that in the past, patents have been allowed to issue at which you have doubtless wondered, so inconsistent do they seem with existing laws, but the public can form no conception of the ignorance of alleged inventors in this art. So mysterious is the art to every one, that in the depths of that mystery reside visions of untold fortunes in alleged inventions which never had a conception other than in the murky brain of their mysterious authors.

Our chief difficulty lies in electro-medical appliances, and the alleged inventions in this direction are legion.

I remember a few years ago, an applicant filed an application for curing nervous affections. It consisted of a copper wire earthed at both ends and carried over the bed of the patient in a north and south direction; that was all. Of course, it was refused for lack of utility, whereupon the applicant produced the affidavits of at least a dozen neighbors to prove that his wife was benefited and restored to health by the use of this simple and alleged effective device. This availed him naught, a patent was refused, and he appealed his case to a higher tribunal, where he again lost.

Another instance I recall is the small neck battery adapted to be worn about the neck of the patient, being about two inches in diameter, and having no excitant. It was refused as being inoperative. The applicant, not to be daunted, was cunning enough to place upon the exterior surface a design, and to take a design

patent therefor, thus succeeding in accomplishing his end by getting the seal of the Patent Office. I have since seen a printed book of over 2,000 pages of testimonials from persons benefited by this alleged great electrical curative.

In another instance, an applicant devised an apparatus for generating steam in locomotive boilers, without the use of wood or coal. He first generated steam in the usual manner by the use of coal, and then caused this steam to actuate a local engine, and from it a dynamo, which generated electricity. This electricity actuated an electrical heater under the boiler, so that after once having started his locomotive, of course no more fuel was necessary. A clear case of perpetual motion. He was required to furnish a working model, which has not yet been received.

Perhaps the most amusing application which ever came under my observation, is that for an improved "Method of Obtaining Rain by Art." I will take the liberty of quoting from the papers, in order that you may form some idea of the peculiar idiosyncracies of this inventor.

He says:

"The object of my invention is to obtain rain by art as required, and where required on the earth, snow falling in colder regions, thus rendering the deserts fruitful, and in time D. V. opening up the Polar regions for settlement, and by withdrawing the rain from the atmosphere, relieving the tension from the ice in the Polar basins, thereby tending to preserve this planet, with all its inhabitants, from the destruction which is imminent, 2d of Peter, Chapter III, and Daniel IX–25, being in danger of fulfilment."

"I use a captive balloon, the cable being attended by a cable or wire to the earth. This cable or wire may be covered with lamp-black, if required, to cause it to absorb solar heat and partially melt ice spicula attaching themselves to it, thereby preventing its breakage.

"The electricity is conducted from the higher strata of the atmosphere in such a way as to produce intense heat and melt floating ice spicula in the air, and precipitate it as rain.

"In this way, the temperature of the higher atmosphere will be lowered, floating ice spicula will be disseminated and gradually the increase continued. Precipitation of ice at the poles of the earth

will not only be discontinued, but a counter action will be set up, bringing the ice from the poles to the equator, and dissipating it as rain in the desert and other arid regions."

His specification is at once a curious medley of scriptural prophesies and alleged scientific facts, the latter to be found only in the curious mind of the inventor; it is not more curious, however, than is an assignment filed by the inventor, which I quote in full as follows:

"Should I die, before the patent for obtaining rain by art is applied by me, I desire the government to work the patent, devoting half the profits to endow the widows' and orphans' homes, into which no clergymen will be allowed; the only prayers to be offered within the walls being those in Holy Scriptures; the only praise to God being the Psalms of David, and other songs of praise in the Holy Bible; the orphans to be instructed into Holy Scripture from infancy, such portions as are suited to their years. When beyond the age of twenty-one years (seventeen females), each to either translate from the Hebrew or Greek the whole Holy Bible, or write a copy of it with their own hand in their own language. The males not to marry until thirty-three years, the females until the age of twenty-five years. Should they become widows or widowers, and wish to marry again, they shall only marry widows or widowers of proportionate age; each orphan to be thoroughly instructed into that branch of science or art to which their mind shows a natural bent, scientific agriculture being prominently held forth to those who wish to adopt it; the girls to be fitted for the positions of governesses, teachers, etc., the widows to be taught branches of needle work, knitting, etc., so that the result of their labors may be devoted to the benefit of the inmates (and if possible to outside poor) in clothing, etc.; prayer and praise to be offered three times daily to the Almighty God. The use of flesh as food, if found practicable, under the observation of unprejudiced, scientifically educated physicians to be prohibited. Abundance of all edible vegetables, grain, etc., of which the leguminous will be in large proportion together with milk, butter, cheese, honey and fruits to be used. From the age of twenty-four to twenty-nine years, the males to contribute one-third part of the net profits of their labor towards the further endowment of their home. The right of amending this testimony for the benefit of all is reserved by me.

"I desire all the nations using the methods of my discovery, to similarly endow such widows' and orphans' homes.

"The other half of the profits to be given to my poor relatives, to be invested by them in profitable securities for their own use and benefit."

These are fair samples of many alleged inventions, which yearly come before the electrical examiner of the Patent Office, and as surely find themselves buried in the record of abandoned applications.

You will, of course, appreciate the fact that but little can be said of the secret history of invention, for the reason that the policy long pursued of preserving pending applications in secrecy must necessarily impress one with its entire fairness to all.

I have made no breach of my official relations in enumerating the cases above referred to, for the reason that it is entirely apparent that these cases must rest without the possibility of ever being blessed with the official seal of the Patent Office.

This unwritten history embraces also many inventions of great practical utility which lie buried in secrecy for reasons known only to their authors; they tell oftentimes the sad story of want, privation, and suffering, and sleep for years only to be resurrected after some more fortunate independent inventor has succeeded in reaching the desired goal.

There is very much of interest and importance in this secret history, and were the records of abandoned cases made public, as in my opinion they should be, the art would receive much that is valuable which will now remain a sealed book forever.

In conclusion, I beg to call attention to the very important position which the Patent Office records hold in the written history of the art and to the fact that our patent system is the best which the civilized world ever knew.

We stand to-day at the head of the civilized world as being the one nation noted for its great inventions. Our ingenuity as a nation of inventors is far-famed. It is due not alone to a peculiarly ingenious people, but rather to the fact that the humblest citizen realizes that for a mere pittance, he can patent and secure from his government a monopoly of his invention for a limited time.

The system has stimulated inventive genius wherever it offers itself, and to-day we find ourselves a nation of educated people

whose homes are surrounded with all the comforts which civilization can give us.

Education has joined issue with ingenuity and the two march hand in hand, each stimulating the other and each vieing with the other in seeking to see where and how the most can be done to elevate the human race to the plane of an all-wise Creator.

Who can tell where it will end? Who can tell what will be the future of such a nation?

BOOK NOTICE.

PRINCIPLES OF ECONOMY IN THE DESIGN OF METALLIC BRIDGES. By Chas. B. Bender. New York: John Wiley & Sons.

To those engineers who are dissatisfied with the meagre efforts heretofore made toward solving the problem of economically proportioning truss-bridges, this work will perhaps be of interest. Mr. Bender begins with criticising the so-called Rankine formula for the ultimate strength of struts, and shows clearly an anomaly in it. He proposes as a remedy, however, another formula equally empirical, founded upon scattered data. The fact is that, when dealing empirically with a scientific subject, every experimenter arrives at an expression of his own, which he maintains against all comers. Of course, better rough approximations by empiricism than guesses; but no satisfactory results will ever be had until the laws in operation have been discovered and measured. Patient experiment and study alone will reveal these laws; they may escape our grasp for a while, yet only for a while. In regard to rupture by tension and compression, such complex action occurs apparently after passing the limit of elasticity, that some engineers have turned their attention solely to fixing this limit, and making their factors of safety depend upon it rather than upon ultimate strength. The theory of elasticity has been much assailed, usually by those who are not aware of its possibilities, still it has survived all attacks. It may, with judgment, be applied to columns quite as well as to solid girders. What takes place when elasticity fails is, in practice, of little interest to the engineer. A structure is already useless if the strains through it reach the limit of elasticity of its material. Besides, the study of material under strains is much simpler below this limit than above it, and experiments confined to elasticity are more reliable than when extended to ultimate strength.

After a rather obscure article on the effects of repeated strains on tension members, the author enters really upon his subject. He obtains expressions for the volume of material in various kinds of trusses, under the favorable supposition of equal loads at their apices, and by these expressions deduces certain laws of economical proportion. He, moreover, compares the different shapes and kinds of trusses in regard to their consumption of material, and grows enthusiastic over American systems of bracing. Next

follows a long discusion of the economy of cantilever bridges, and of their possibilities for the enormous spans in contemplation through their use. The suspension bridge, also, is discussed with special reference to its stiffening girder. The lateral bracing of truss bridges receive some consideration, and finishes the work. In an appendix is reprinted, from the *Railroad Gazette*, the account of some experiments on steel and iron girders conducted in Europe.

With few exceptions the mathematics employed by Mr. Bender are simple; although they may prove objectionable to those who look upon algebraic symbols as stumbling blocks. Much information, didactic and descriptive, is scattered through the book; and very interesting are the historical details connected with the forms and improvements of bridges. The labor performed in Germany especially is reviewed by Mr. Bender. We recommend this work to the profession. C. A. E.

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